Herring Stock Estimates from Diving Surveys of Spawn for Georgia and Johnstone Straits in 1985

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PREFACE

An early draft of this manuscript was presented at the September 1985 Herring Stock Assessment Committee meeting. At that time, spawner biomass estimates from diving surveys were made using a model which predicts egg density from visual observations and spawn sample weights. Since then, eggs in preserved spawn samples have been counted and the results were used in this analysis. As well, estimates of egg density in spawns surveyed only from the surface were revised. This has resulted in an increase in the estimates of adult herring biomass in the combined Georgia and Johnstone straits from 21,594 to 31,866 tonnes.

ABSTRACT

Schweigert, J. F. and C. W. Haegele. 1988. Herring stock estimates from diving surveys of spawn for Georgia and Johnstone straits in 1985. Can. MS Rep. Fish. Aquat. Sci. 1972: 63 p.

Using the results of spawn surveys, we estimated that 24,003 tonnes of herring spawned in Georgia Strait in 1985. The roe fishery removed another 6565 tonnes of potential spawners from Area 14. This yields a combined estimate of 30,568 tonnes for the prefishery spawner biomass in Georgia Strait. bOf this total, 16,517 tonnes were estimated to have spawned in Area 14, mostly on Denman Island with minor spawnings on Hornby Island and along the Vancouver Island shoreline from Nile Creek to Qualicum Beach. In Area 15, 1614 tonnes were estimated to have spawned on Harwood and Savary islands and from Sliammon to Dinner Rock on the mainland shore. An estimated 5707 tonnes spawned in Area 17: 128 tonnes on Thetis Island and 5579 tonnes from north of Yellow Point south into Ladysmith Harbour. Another 165 tonnes were estimated to have spawned in Area 18.

Only the early spawns in Johnstone Strait were surveyed by divers. Surface survey results were used to estimate the spawning biomass for the later spawns. The spawner biomass for Johnstone Strait was estimated at 1298 tonnes of which 1295 tonnes spawned in Area 12 and 3 tonnes spawned in Area 13. The total prefishery adult biomass for both Georgia and Johnstone straits was therefore estimated to be 31,866 tonnes in 1985.

The spawns were in more shallow water and on more gently sloping beaches in Area 14 than in Area 17, although spawns were significantly wider in Area 14. Most of the spawn was deposited between 1 m above to 3 m below chart datum, and egg density declined with depth.

RESUME

Schweigert, J. F. and C. W. Haegele. 1988. Herring stock estimates from diving surveys of spawn for Georgia and Johnstone straits in 1985. Can. MS Rep. Fish. Aquat. Sci. 1972: 63 p.

Les auteurs ont estimé, à partir des résultats de relevés de ponte, que 24 003 tonnes de harengs avaient frayé dans le détroit de Géorgie en 1985. La pêche du hareng rogué a prélevé 6 565 tonnes supplémentaires de géniteurs potentiels dans la zone 14. La biomasse totale de géniteurs, avant la pêche, était donc estimée à 30 568 tonnes dans le détroit de Géorgie. De ce total, les auteurs ont estimé que 16 517 tonnes de harengs avait frayé dans la zone 14, surtout à l'île Denman bien qu'il y ait eu des pontes limitées à l'île Hornby et le long de la côte de l'île Vancouver, du ruisseau Nile à la plage Qualicum. Dans la zone 15, les géniteurs, estimés à 1 614 tonnes, ont frayé aux îles Harwood et Savary et le long de la côte, de Sliammon à Dinner Rock. Dans la zone 17, ces valeurs sont de 128 tonnes à l'île Thetis et 5 579 tonnes du nord de la pointe Yellow à, vers le sud, Ladysmith Harbour pour un total de 5707 tonnes. Dans la zone 18, le volume de harengs ayant frayé a été estimé à 165 tonnes.

Seules les premières pontes du détroit de Johnstone ont fail l'objet de relevés par plongeurs. La biomasse de géniteurs des pontes subséquentes a été estimée à partir de relevés faits en surface. Dans le détroit de Johnstone, cette biomasse a été estimée à 1 298 tonnes dont 1 295 tonnes dans la zone 12 et 3 tonnes dans la zone 13. La biomasse totale d'adultes d'avant la pêche de 1985 dans les détroits de Géorgie et Johnstone a donc été estimée à 31 866 tonnes.

Les oeufs ont été déposés dans des eaux moins profondes et sur des plages en pente plus douce dans la zone 14, comparativement à la zone 17, mais ils étaient beaucoup plus étalés dans la zone 14. La plupart des oeufs se trouvaient dans la couche située entre 1 m au-dessus et 3 m en-dessous du zéro des cartes et leur densité déclinait avec la profondeur.

INTRODUCTION

The abundance of herring spawning in Georgia and Johnstone straits declined over several years to a recent low in 1984 (Haist et al. 1985). Herring spawns in portions of Georgia Strait have been surveyed by divers in 1976 (Haegele and Humphreys 1977), 1978 (Haegele et al. 1979b), and 1983 (Haegele and Schweigert 1985), but never has there been an attempt by divers to survey all the spawns. Johnstone Strait spawns have never been surveyed by divers. Concern about the low levels of herring spawning stocks in Georgia and Johnstone straits in recent years and the potential effects of even moderate herring roe fisheries in these areas on the recovery of these stocks prompted us to conduct an intensive diving survey of this area in 1985. The results are summarized in this report.

METHODS

Herring spawns were surveyed independently by SCUBA divers and traditional surface survey techniques. In the surface survey, visual observations were made from the surface from a boat. Frequently a viewing box was used to increase the visibility of the bottom. Grapples were used to detect the presence of and obtain samples of spawn. From these observations, the length and width of spawn and the number of layers of eggs were estimated. The proportion of the area of the spawn devoid of eggs or vegetation (bare area) was also estimated.

The diving survey followed a two-stage sampling design (Schweigert et al. 1985). Transects perpendicular to the shore were the primary sampling unit and 0.5 sq. m quadrats sampled along the transect were the secondary sampling unit. Samples consisted of all the rooted or attached vegetation, and the eggs adhering to it, within the quadrat. Layers of eggs, percent cover of the vegetation, and the dominant vegetation type were estimated by divers for each quadrat. Samples were weighed and weighed subsamples were preserved in Gilson's fluid from which egg counts were obtained. In Area 12, egg counts for only 37 of the 60 samples were obtainable because of improper sample preservation. As the egg counts for these 37 samples appeared to be unrealistically low, averaging approximately 12,000 eggs per sq. m, we felt it prudent to predict egg density for the 60 samples from the observations on vegetation type, percent cover of vegetation, layers of eggs, and sample weight by using instead a model modified from Schweigert and Fournier (1982). Eggs on the bottom substrate were estimated from diver estimates of layers of eggs and percent of bottom covered by vegetation (Haegele et al. 1979a) and added to eggs on vegetation. Depths at sample sites were measured by divers and were corrected to chart datum using water levels observed at applicable tide gauge installations (Tides and Currents, Institute of Ocean Sciences, Sidney, B.C.).

Transects were established at nearly equal intervals along the length of the spawn and samples were collected at equal intervals along each transect with the spacing determined by the width of the spawn. The mean egg density and 95% confidence interval were calculated for each spawn and transect means were weighted by transect lengths (Schweigert et al. 1985). In Area 12 the vegetation zone was generally 5 m or less in width so that it was not possible to lay transects. The vegetation was a narrow rockweed zone on the boulders and the rock face of the cliffs. Consequently, we randomly sampled a single quadrat at each transect location. The inner and outer edge of spawns were determined from measurements along transects. The limits of a spawn beyond the outer transects was determined by exploratory dives. This information was plotted on maps of marine vegetation at scales of 1:4800 and 1:6000 (e.g. Haegele and Hamey 1981), the boundaries of the spawn contoured, and the area of the spawn measured. Spawner biomass (tonnes) was estimated as the product of spawn area, egg density, and 0.00000001, which reflects an assumed 200 eggs per gm female weight (Hay 1985) and a 1:1 sex ratio.

For spawns in Johnstone Strait surveyed only with surface surveys, the reported spawn area was adjusted upwards using the ratio of diver area to surface survey area from dual surveyed spawns. For spawns in Georgia Strait surveyed only from the surface, the observed length and an adjusted width was used to calculate area. The equation for this adjustment is (Haist et al. 1986):

$$(1)\quad Width_{adj} = \exp\left[0.375 \log_e (Width_{obs}) + 3.401\right]$$

Egg density for these spawns was either the mean for similar spawns in the Area (Area 12, 13 and 18) or the mean for the Statistical Area (Area 14).

RESULTS

BIOMASS ESTIMATES

We estimated from spawn surveys that 24,003 tonnes of herring spawned in Georgia Strait in 1985 (Fig. 1). Some spawning occurred in all four Statistical Areas (14 to 18) but 80% occurred in two large spawnings: one at Denman Island in Area 14 and one at Yellow Point in Area 17. Another 6565 tonnes were taken by the roe fishery in Lambert Channel (Area 14), 2879 tonnes by seine and 3686 tonnes by gillnet. The total prefishery biomass estimate for Georgia Strait therefore was 30,568 tonnes. We estimated that 1298 tonnes spawned in Johnstone Strait (Fig. 2). Virtually all of the spawning occurred in Statistical Area 12 and most of this occurred in two waves in Wakeman Sound and Knight Inlet. We describe the individual spawns in each of these Areas below.

Area 12

The spawnings in Area 12 tend to be small and scattered spatially, occurring over a protracted period of time. Consequently, the diving survey covered only the first spawn in Knight Inlet (March 8 to 18) and the second spawn in Wakeman Sound (March 18 to 20). A second wave spawned in Knight Inlet from April 4 to 7 and a first wave spawned in Wakeman Sound from March 8 to 10. Other spawns in the Area occurred in Beaver Harbour from March 20 to 27 and from April 4 to 8 in Hardy Bay, Beware Passage, O'Brien Bay, Simoon Sound, and Kenneth Passage. The spawns not surveyed by divers were surveyed from the surface (Table 1). The first wave spawn in Knight Inlet (Fig. 3 and 4) covered 12.03 ha and was deposited by 383 tonnes of fish while the second wave covered 10.62 ha and accounted for 338 tonnes (Table 2). The egg density in Knight Inlet was estimated at 318,401 eggs per sq. m. The first wave spawn in Wakeman Sound covered 5.99 ha and was deposited by 228 tonnes while the second wave spawn (Fig. 5) covered 5.04 ha and was deposited by 192 tonnes at an egg density of 380,349 eggs per sq. m. The other spawns accounted for an additional 154 tonnes.

Area 13

There was one spawning on April 7 surveyed from the surface in Area 13. The observed area was adjusted upward using the ratio of diver survey area to surface survey area from the dual surveyed spawn in Knight Inlet and the Knight Inlet egg density was used to calculate spawner biomass. Three tonnes were estimated to have spawned on 0.065 ha.

Area 14

The major spawning and the only roe fishery on the south coast in 1985 occurred in Lambert Channel between Denman and Hornby islands. Approximately 80% of the estimated 16,517 tonnes in Area 14 (Table 3) spawned along the eastern shore of Denman Island from Longbeak Point, past Komas Bluff, Fillongley Park and Whalebone Point, to Boyle Point (Fig. 6 to 10). The spawn on Denman Island occurred between March 7 and 10 and was estimated to have been deposited by 13,647 tonnes. Another 238 tonnes spawned March 10 and 23 on Hornby Island at Shingle Spit (Fig 9) and Collishaw Point (Fig. 11). Egg density at Denman Island was 403,252 eggs per sq. m and 69,365 eggs per sq. m at Hornby Island. The remainder of the spawn in Area 14 occurred along the Vancouver Island shoreline. A spawn on March 24 at Nile Creek (Fig. 12) was surveyed by divers but not from the surface and was estimated at 89 tonnes. The egg density was a low 34,429 eggs per sq. m. Three other spawns, at Little and Big Qualicum rivers and at Qualicum Beach, occurred on March 27 and 31 and were surveyed from the surface only. It was estimated that 2543 tonnes spawned there. The area of these spawns was estimated from surface survey observed lengths and widths, adjusted using equation (1), and the Area 14 egg density of 358,424 eggs per sq. m was used to calculate spawner biomass. With the inclusion of the 6565 tonnes roe catch, the prefishery adult biomass for Area 14 was 23,082 tonnes.

Area 15

There were three spawns in Area 15 that occurred between March 6 and 18. The spawns on the western shore of Harwood Island (Fig. 13) and the southern tip of Savary Island (Fig. 14) were deposited by 628 and 76 tonnes, respectively. The third spawn was on the mainland shore, centered at Atrevida Reef, and was continuous from Sliammon to Dinner Rock (Fig. 15). This spawn was deposited by 910 tonnes. Egg density ranged from 48,036 eggs per sq. m at Savary Island, where the vegetation was very patchy, to 192,245 eggs per sq. m at Atrevida Reef. The total spawner biomass in Area 15 was 1614 tonnes.

Area 17

There were two spawns in Area 17. On Thetis Island, herring spawned from March 29 to April 3 from Crescent Point north to Fraser Point (Fig. 16 and 17). Egg density was 112,500 eggs per sq. m and 128 tonnes spawned here. The major spawning in Area 17 occurred from March 29 to April 3 and was centered at Yellow Point, extending from north of Yellow Point (Fig. 18) to Kulleet Bay (Fig. 19) and past Coffin Point into Ladysmith Harbour (Fig. 20). Egg density was 419,148 eggs per sq. m and an estimated 5579 tonnes spawned here. The total spawner biomass estimate for Area 17 was 5707 tonnes.

Area 18

Area 18 spawns were not surveyed by divers and the surface survey found the spawns so light and patchy that it was not possible to determine egg layers. These spawns were the earliest in Georgia Strait, occurring on March 3. There were four patches of spawn in Annette Inlet and one patch of spawn in Selby Cove, both on Prevost Island. The area of these spawns was estimated from surface survey observed lengths and widths, adjusted using equation (1). The egg density of 34,429 eggs per sq. m from Nile Creek, which was the lightest spawn surveyed by divers, was used to estimate spawner biomasses of 25 tonnes for Selby Cove and 140 tonnes for Annette Inlet, for an Area 18 total of 165 tonnes,

SPAWN DISTRIBUTION

Spawn was widest in Area 14, where average transect length was 143 m. In Area 15 and 17 average transect lengths were similar, 70 and 63 m, respectively, and significantly shorter ($P < 1\%$, Student t-test) than in Area 14 (Fig. 22). This can be partially attributed to beach slope. In Area 17 the beach slope averaged 0.096, a rise of 9.6 m every 100 m, while in Area 14 the average beach slope was 0.033 (Fig. 22). However, in Area 15 beach slope was similar to beach slope in Area 14, but spawn was deposited over a narrower depth range than in Area 14. The difference between the average inner edge of spawn (IES) and outer edge of spawn (OES) for Area 15 was 1.9 m, from 0.5 m above to 1.4 m below chart datum), while for Area 14 this

difference was 2.7 m, from 0.8 m above to 1.9 m below chart datum (Fig. 22). Spawn was deposited over the widest depth range in Area 17, where the average IES was 1.1 m above chart datum and the average OES was 2.8 m below chart datum, a difference of 3.9 m. The maximum depth to which spawn occurred in Area 17 was 11.1 m below chart datum, while in Area 15 and 14 spawn occurred to 5.1 m and 4.9 m below chart datum, respectively.

The type of vegetation on which the eggs were deposited, the mean (Wilcoxon median) percent cover of the vegetation, the mean layers of eggs, the mean egg density, and the mean sample weight were determined by depth interval. Depth intervals chosen were intertidal (above 0 m chart datum), upper subtidal (between 0 and 3 m below chart datum), middle subtidal (between 3 m and 6 m below chart datum), and lower subtidal (deeper than 6 m below chart datum). In the intertidal interval, sea grasses, rockweed, other brown algae (Sargassum muticum), and filamentous red algae were the most common vegetation; in the upper subtidal interval, sea grasses, kelp, other brown algae, and foliose and filamentous red algae were the the most common vegetation (Fig. 23). The vegetation differed significantly between depth intervals within Statistical Areas ($P < 1\%$, Chi-square) and also between Statistical Areas. For example, sea grasses and rockweed were more commonly observed in Area 17 than in Area 14, while foliose and filamentous red algae were more commonly observed in Area 14 than Area 17. The percent cover of the vegetation decreased with depth interval and the differences were significant (Mann-Whitney test) between intervals for the major Denman Island spawn (Fig. 24). Egg layers and egg density also decreased with depth interval and the differences were significant between the intertidal and upper subtidal interval for the Denman Island spawn and between the intertidal and middle subtidal and the upper and middle subtidal intervals for the other major spawn at Yellow Point (Fig 24). The weight of samples also decreased with depth but the differences between depth intervals was generally not significant, except between the upper and middle subtidal intervals at Denman Island (Fig 24). Percent cover of vegetation in the subtidal depth intervals was significantly higher at Yellow Point than at Denman Island, but in the intertidal interval the percent cover was similar. Egg layers, egg density and sample weight were similar for Denman Island and Yellow Point at all depth intervals. Egg layers and egg density for the minor spawns were generally lower at all depth intervals than for the major spawns.

In Area 14 and 17, 29% of the spawn area was in the intertidal interval and 55% was in the upper subtidal interval (Fig. 25). However, 50% of the eggs were deposited in the intertidal interval in Area 14 while only 38% of the eggs were deposited in the intertidal interval in Area 17. In Area 15, 37% of the spawn area and 42% of the eggs were in the intertidal interval. Only in Area 17 was spawn found in the lower subtidal interval, where 4% of the area and < 1% of the eggs occurred.

DISCUSSION

Confidence intervals (95%) for egg densities were quite broad, from 56% to 135% of the mean, for some of the minor spawns (Hornby, Thetis and Savary islands and Nile Creek), but within 33% to 42% of the mean for the major spawns (Table 2) and within 28% and 42% of Statistical Area means (Table 3). Sums of spawner biomass for individual spawns were nearly identical to biomass estimates using Area means (Table 3). Hence, despite the high variance, spawner biomass estimates for individual spawns are probably quite reasonable. The high variance in some of the estimates may be the result of insufficient sampling. The sampling design for a minimum of 5 samples per transect was exceeded for all spawns, but the requirement for 4 transects per km was never achieved (Table 4), due mainly to time constraints. The optimal samples per transect (after Schweigert et al. 1985) was nearly achieved or exceeded for all spawns and the optimal transects per km was also nearly achieved or exceeded for all but three of the minor spawns (Hornby, Thetis, and Savary islands) where the optimal transects per km exceeded 10 transects per km (Table 4).

The distribution of spawn by depth was similar to that documented in diving surveys in Georgia Strait in 1978 (Haegele et al. 1981) and 1983 (Haegele and Schweigert 1985). That is, percent cover of vegetation, layers of eggs, and egg density decline with depth. Most spawn in Georgia Strait is deposited higher than 3 m below chart datum, but most spawn does not extend higher than 1 m above chart datum. Since low tides never fell below 1 m above chart datum during the egg incubation period in 1985, very little of the spawn became exposed at low tide. There were some between Area differences in spawn distribution, mostly dictated by beach slope and the attendant vegetation differences. The beach slope was steeper in Area 17 than in Area 14 and consequently spawns were narrower and deeper in Area 17.

Herring spawning stocks in 1985 in Johnstone and Georgia Straits were expected to be at lower levels than in 1984 (Haist et al. 1985). This is the first year of complete diving surveys in Georgia Strait so it is very difficult to determine trends from direct estimates of spawner biomass from diving surveys. Diving surveys estimated 5136 tonnes of spawners at Denman and Hornby islands in 1983 and 10,052 tonnes were harvested that year in the Lambert Channel roe fishery for a total prefishery adult biomass of 15,188 tonnes. In this survey (1985), we estimated 13,885 tonnes of spawners and there was a 6565 tonnes roe fishery for a total adult prefishery adult biomass of 20,450 tonnes for the same area (Denman and Hornby islands and Lambert Channel). Hence, stocks in this major fishing area appear to have increased and supporting evidence, from the available diving survey information, of the continuing downward trends, projected by the assessment models, is equivocal.

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Table 1. Herring spawn survey results for Johnstone and Georgia straits in 1985. [Adjusted area = length * width * (100 - % bare)].

Location	Diving survey						Surface survey				
	No. of transects	Length (m)	Av. transect length (m)	Area (ha)	Av. egg layers	No. of patches	Length (m)	Av. width (m)	Raw area (ha)	Adjusted area (ha)	Av. egg layers
Area 12											
Wakeman Sd.	25	9930	5.08	5.044	0.40	2	9052	2.41	2.181	1.527	1.00
Wakeman Sd.	No survey	-	-	-	-	2	6475	4.00	2.590	2.072	1.00
Knight In.	45	31830	3.78	12.032	0.35	9	23612	3.68	8.882	6.618	1.23
Knight In.	No survey	-	-	-	-	3	15300	5.12	7.840	2.493	1.35
Beaver Hb.	No survey	-	-	-	-	2	1500	14.33	2.150	1.705	0.99
Hardy Bay	No survey	-	-	-	-	1	600	15.00	0.900	0.810	0.49
Beware Pass.	No survey	-	-	-	-	1	250	2.00	0.050	0.018	1.00
O'Brien Bay	No survey	-	-	-	-	1	200	7.00	0.140	0.021	1.00
Simoon Sd.	No survey	-	-	-	-	1	100	6.00	0.060	0.048	1.40
Kenneth Pass.	No survey	-	-	-	-	3	1080	2.42	0.261	0.167	1.52
Area 13											
Deepwater B.	No survey	-	-	-	-	1	650	1.00	0.065	0.065	0.50
Area 14											
Denman I.	29	20100	178.00	338.420	0.48	10	16200	64.10	103.842	56.660	0.76
Hornby I.	10	6900	57.30	34.297	0.23	2	450	23.89	1.075	0.258	0.35
Nile Creek	3	2000	67.67	25.934	0.34	No survey	-	-	-	-	-
L. Qualicum	No survey	-	-	-	-	3	2100	109.52	23.000	17.000	2.04
B. Qualicum	No survey	-	-	-	-	2	1200	200.00	24.000	12.400	2.53
Qual. Beach	No survey	-	-	-	-	2	800	25.00	2.000	0.600	0.63

Table 1 (cont'd)

Location	Diving survey					Surface survey					
	No. of transects	Length (m)	Av. transect length (m)	Area (ha)	Av. egg layers	No. of patches	Length (m)	Av. width (m)	Raw area (ha)	Adjusted area (ha)	Av. egg layers
Area 15											
Harwood I.	9	3000	91.67	38.200	0.42	5	3100	98.71	30.600	23.940	1.87
Savary I.	2	800	81.50	15.720	0.29	2	1400	135.71	19.000	9.500	0.60
Atrevida Rf.	10	7200	49.30	47.358	0.44	10	4650	20.81	9.675	5.250	0.69
Area 17											
Thetis I.	7	3200	48.43	11.419	0.56	3	2700	7.44	2.010	2.010	1.77
Yellow Pt.	30	21000	66.73	133.103	0.53	18	15350	15.34	23.550	23.550	1.68
Area 18											
Selby Cove	No survey	-	-	-	-	1	550	50.00	2.750	2.750	trace
Annette In.	No survey	-	-	-	-	4	2050	154.88	31.750	31.750	trace

Table 2. Estimates of spawner biomass by individual spawn for Johnstone and Georgia straits in 1985. (95% confidence intervals are given in brackets.)

Location	Source (T = transect no.)	Area (ha)	Thousands of eggs per sq. m	Tonnes of Spawners
Area 12				
Wakeman Sd.	25 Observations	5.044	380 (283 to 478)	192 (142 to 241)
Wakeman Sd.	Surface survey	5.990	380 (283 to 478)	228 (170 to 286)
Knight In.	45 Observations	12.032	318 (242 to 395)	383 (291 to 475)
Knight In.	Surface survey	10.620	318 (242 to 395)	338 (257 to 419)
Beaver Hb.	Surface survey	2.912	318 (242 to 395)	93 (70 to 115)
Hardy Bay	Surface survey	1.219	318 (242 to 395)	39 (29 to 48)
Beware Pass.	Surface survey	0.068	318 (242 to 395)	2 (2 to 3)
O'Brien Bay	Surface survey	0.190	318 (242 to 395)	6 (5 to 8)
Simoon Sd.	Surface survey	0.081	318 (242 to 395)	3 (2 to 3)
Kenneth Pass.	Surface survey	0.354	318 (242 to 395)	11 (9 to 14)
Area 13				
Deepwater B.	Surface survey	0.088	318 (242 to 395)	3 (2 to 3)
Area 14				
Denman I.	T 5,6,10-36	33C.420	403 (268 to 538)	13647 (9070 to 18223)
Hornby I.	T 1,2,4,5,8,10-14	34.297	69 (-23 to 162)	238 (0 to 556)
Nile Creek	T 1-3	25.934	34 (15 to 54)	89 (39 to 140)
L. Qualicum	Surface survey	36.649	358 (246 to 471)	1314 (903 to 1725)
B. Qualicum	Surface survey	26.248	358 (246 to 471)	941 (646 to 1235)
Qual. Beach	Surface survey	8.023	358 (246 to 471)	288 (198 to 376)
Area 15				
Harwood I.	T 1,3-10	38.200	164 (98 to 230)	628 (375 to 880)
Savary I.	T 1,2	15.720	48 (6 to 90)	76 (10 to 41)
Atrevida Rf.	T 1-10	47.358	192 (127 to 258)	910 (601 to 1220)

Table 2 (cont'd.)

Location	Source (T = transect no.)	Area (ha)	Thousands of eggs per sq. m	Tonnes of Spawners
Area 17				
Thetis I.	T 1-7	11.419	113 (-1 to 226)	128 (0 to 259)
Yellow Pt.	T 1,3-6,8-13,15-31,33,35	133.103	419 (241 to 597)	5579 (3210 to 7948)
Area 18				
Selby Cove	Surface survey	7.153	34 (15 to 54)	25 (11 to 38)
Annette In.	Surface survey	40.742	34 (15 to 54)	140 (61 to 219)

Table 3. Summary of spawn length and area and estimates of spawner biomass using statistical area mean egg densities. These estimates are compared to estimates derived by summing results for individual spawns from Table 2. (95% confidence intervals are given in brackets.)

Statistical Area	Length (m)	Area (ha)	Thousands of eggs per sq. m	Tonnes	Tonnes (sum)
12	67265	38.510	n.a.	1295#	1295
13	650	0.088	n.a.	3#	3
14	33100	469.571	358 (246 to 471)	16831 (11564 to 22097)	16517
15	11000	101.278	161 (116 to 206)	1629 (1173 to 2085)	1614
17	24200	144.522	374 (216 to 533)	5416 (3128 to 7704)	5707
18	2600	47.895	n.a.	165#	165
Total	138815	801.864		25339	25301

From Table 2.

Table 4. Estimated optimal sampling design to achieve a SE of 25% of the mean (after Schweigert et al 1985) and achieved sampling density for 1985 diving surveys of herring spawn in Georgia Strait.

Location	Samples per transect	Av. transect length (m)	Achieved sampling fraction	Optimal sampling fraction	Achieved transects per km	Optimal transects per km
Denman I.	6.4	178.0	0.036	0.036	1.443	1.070
Hornby I.	4.8	57.3	0.084	0.040	1.449	13.842
Nile Creek	6.7	67.7	0.099	0.046	1.500	2.863
Harwood I.	5.6	91.7	0.061	0.047	3.000	3.049
Savary I.	5.5	81.5	0.067	0.036	2.500	10.009
Atrevida Rf.	5.9	49.3	0.120	0.106	1.389	1.065
Thetis I.	5.7	48.4	0.118	0.140	2.188	13.138
Yellow Pt.	5.3	66.7	0.079	0.110	1.429	1.724

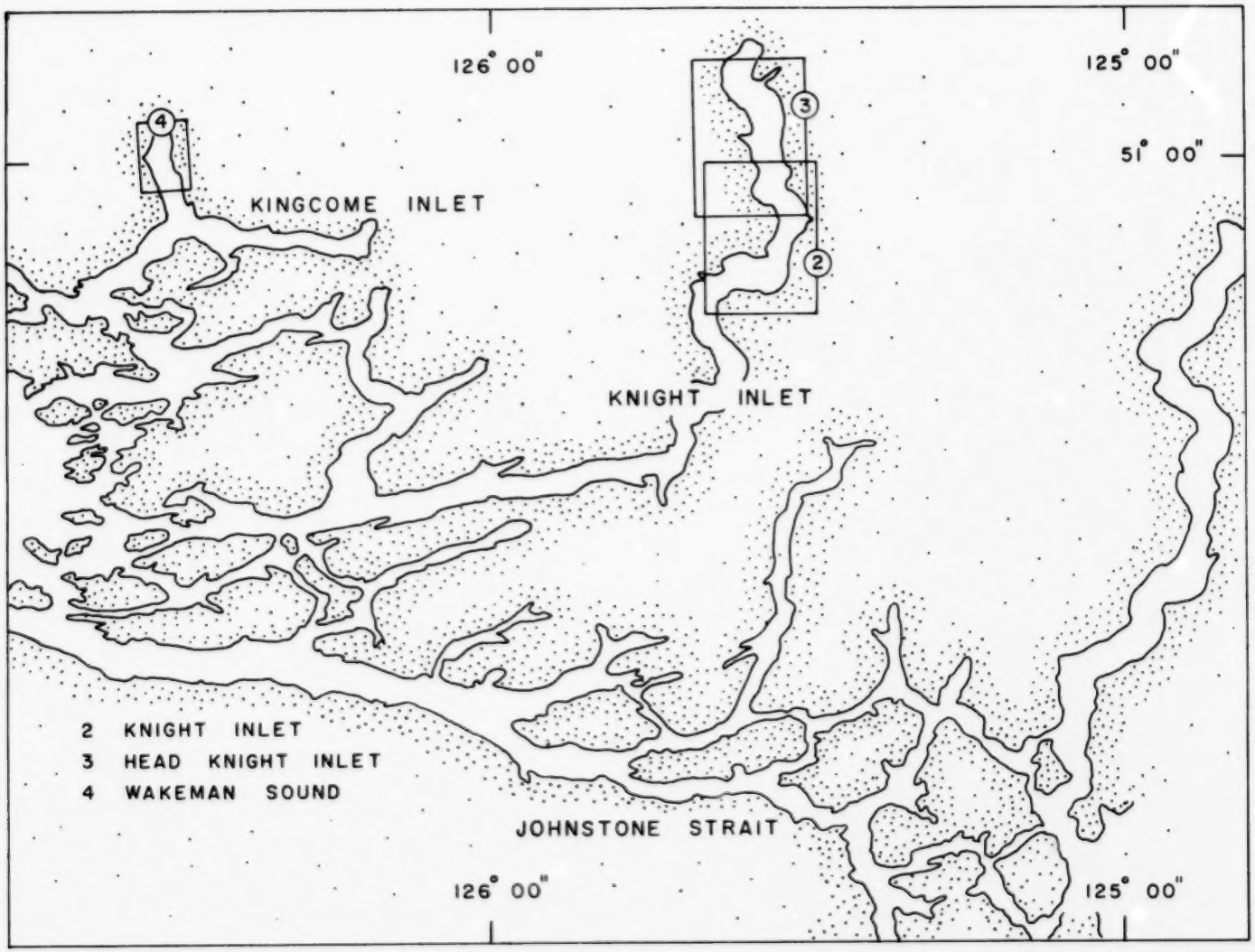

Fig. 1. Georgia Strait study area showing location of spawn sites surveyed by divers. Numbered rectangles 6 to 21 show the location of Fig. 6 to 21.

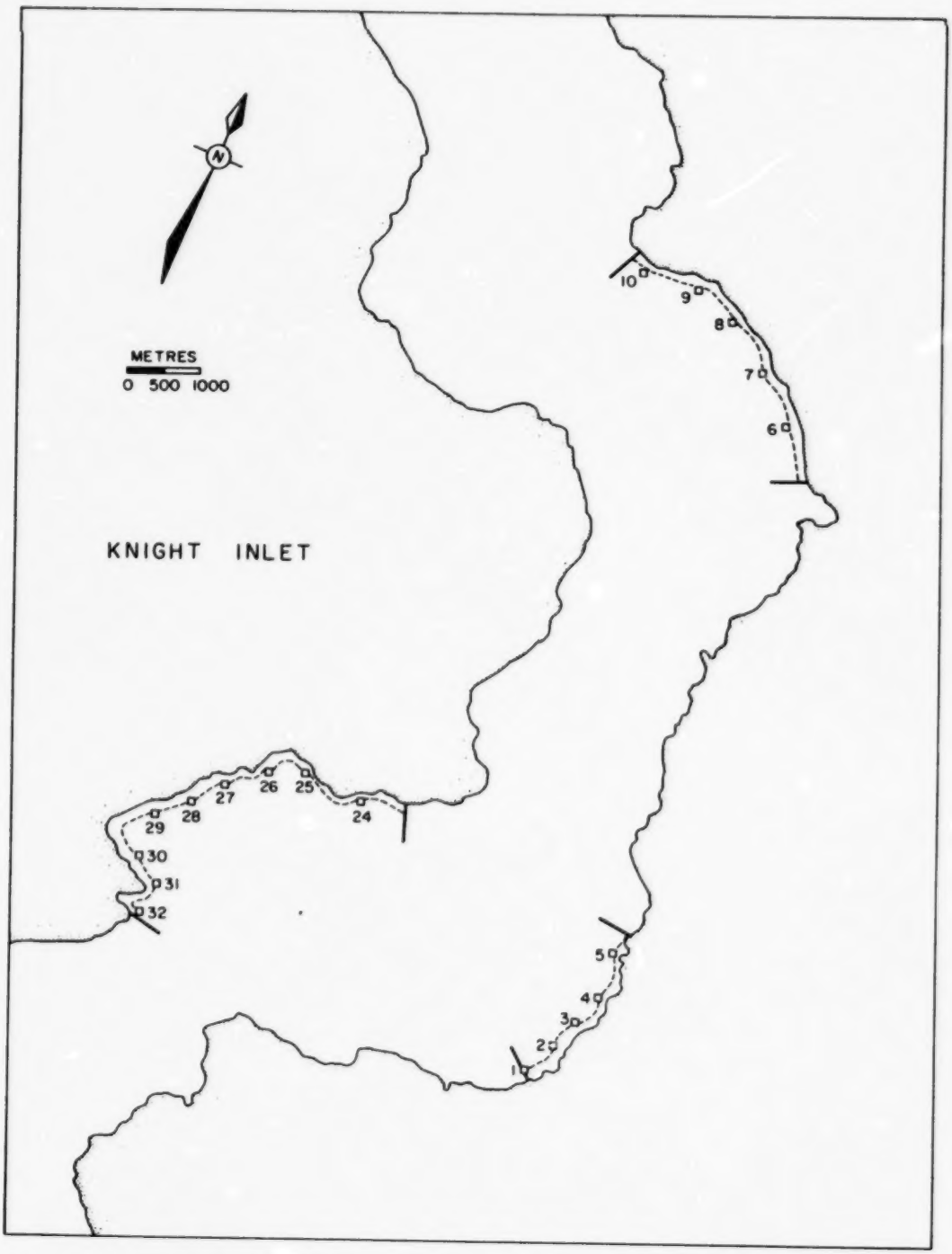

Fig. 2. Herring spawn in Knight Inlet, surveyed by divers in 1985, with sampling locations shown.

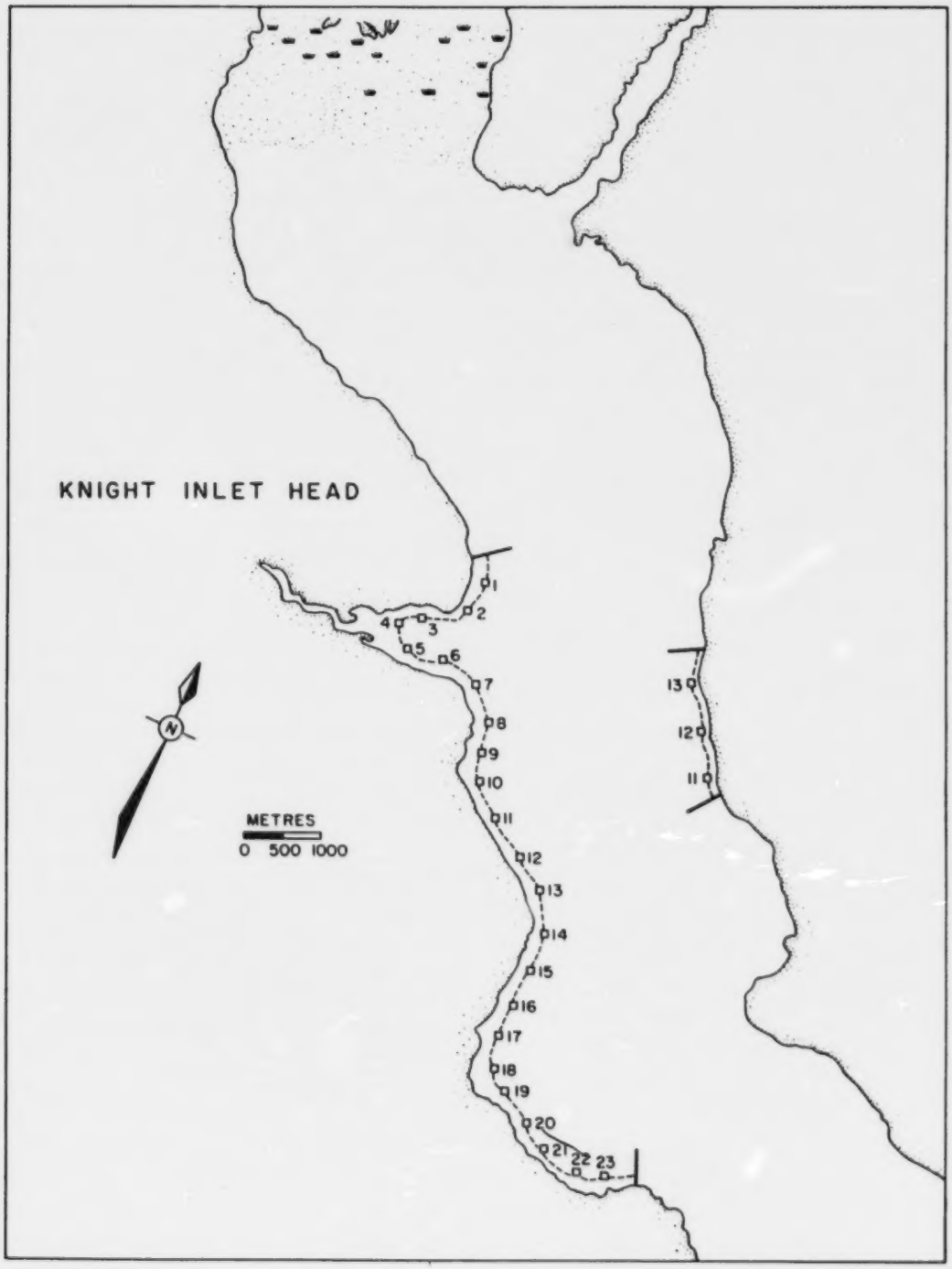

Fig. 3. Herring spawn at the head of Knight Inlet, surveyed by divers in 1985, with sampling locations shown.

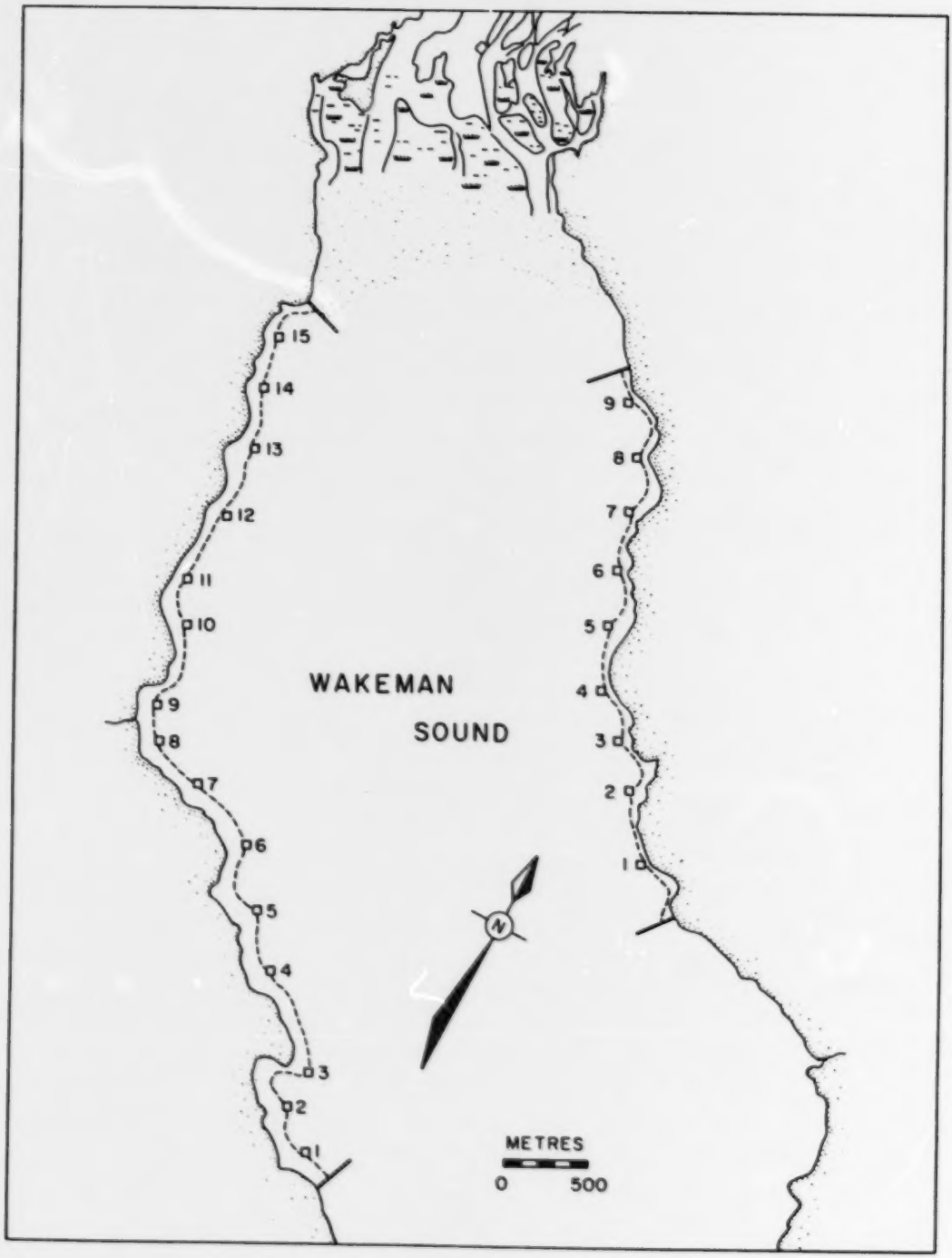

Fig. 4. Herring spawn in Wakeman Sound, surveyed by divers in 1985, with sampling locations shown.

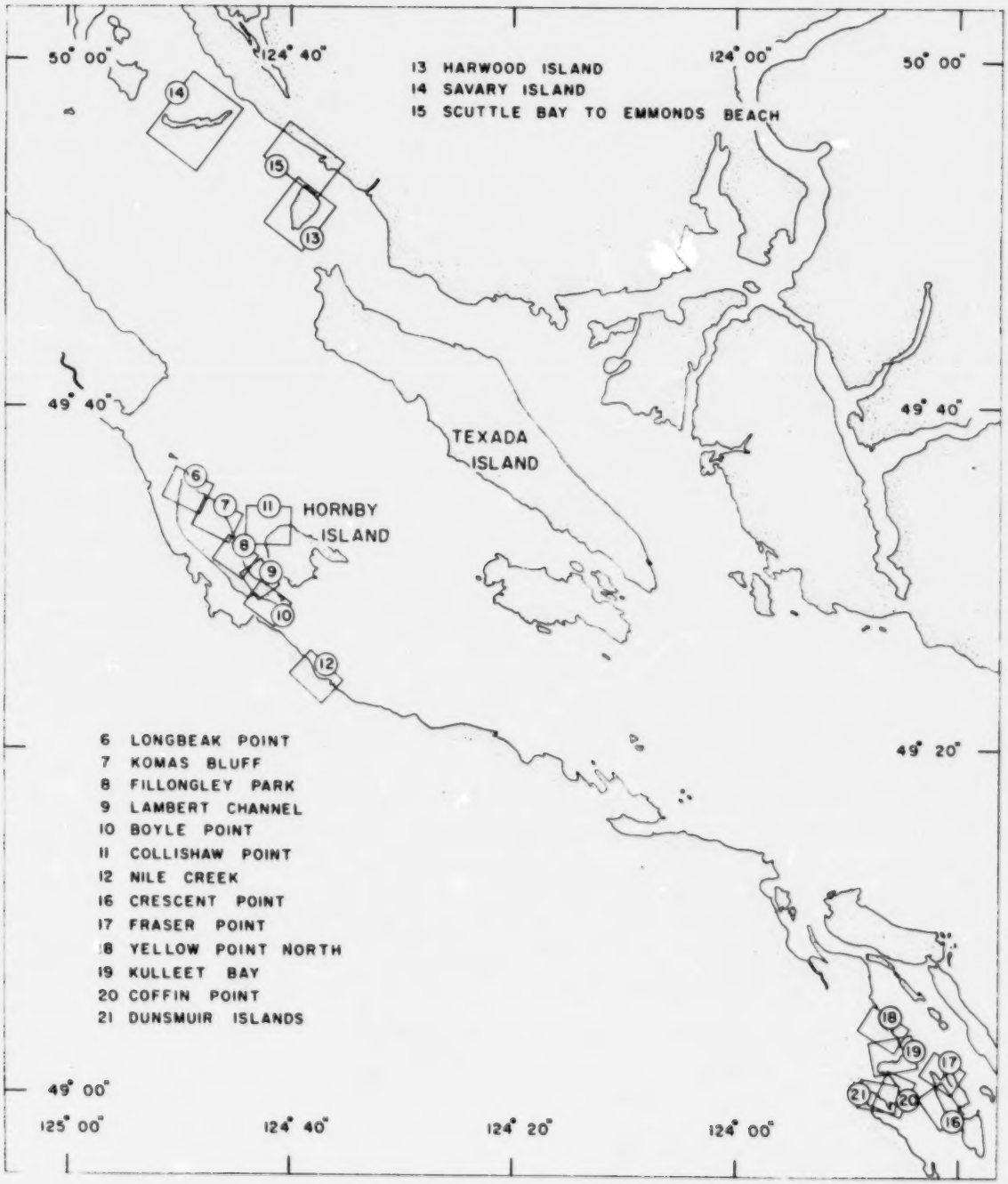

Fig. 5. Herring spawn in Wakeman Sound, surveyed by divers in 1985, with sampling locations shown.

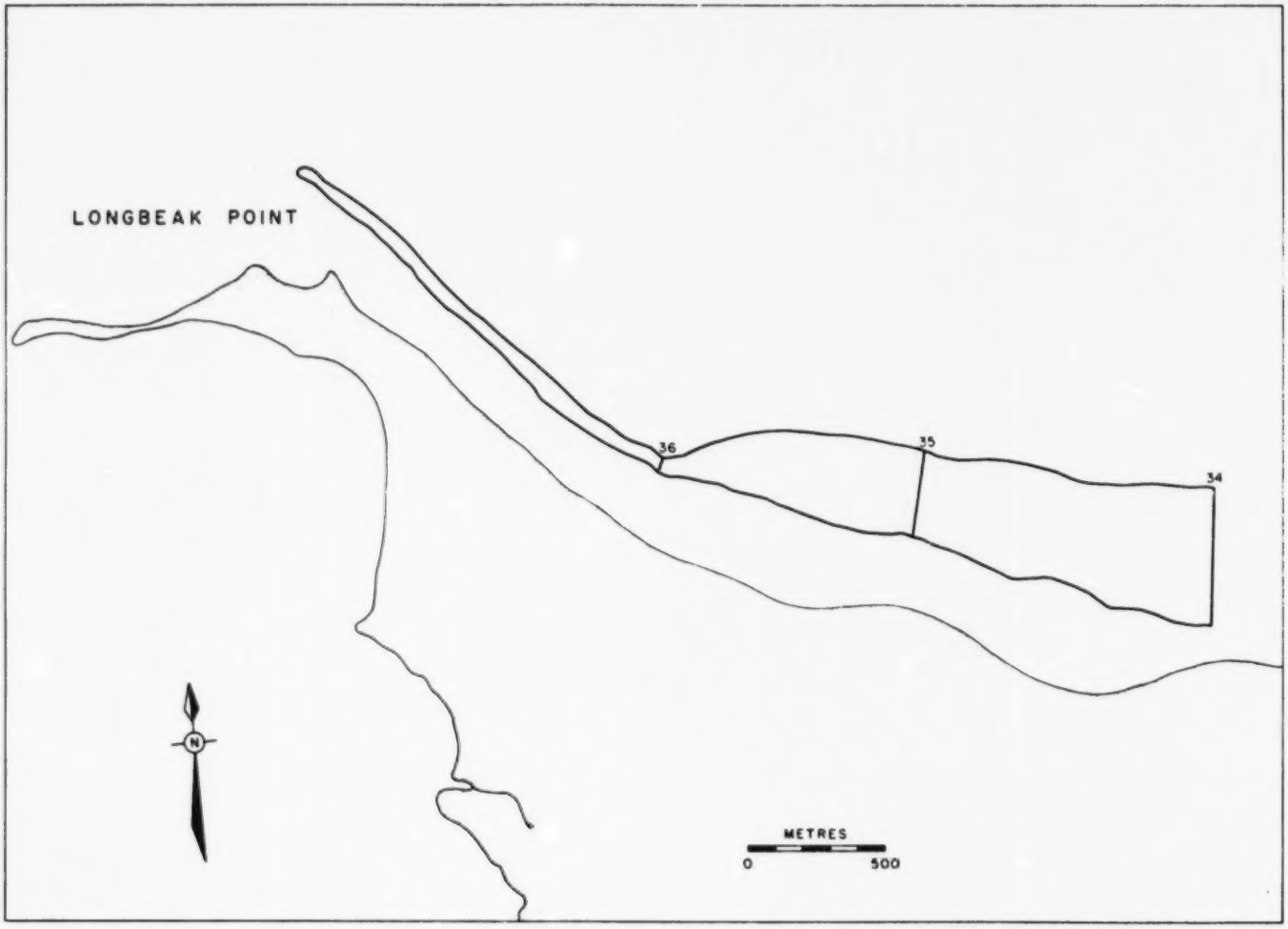

Fig. 6 Herring spawn at Longbeak Point on Denman Island, surveyed by divers in 1985, with transect locations shown.

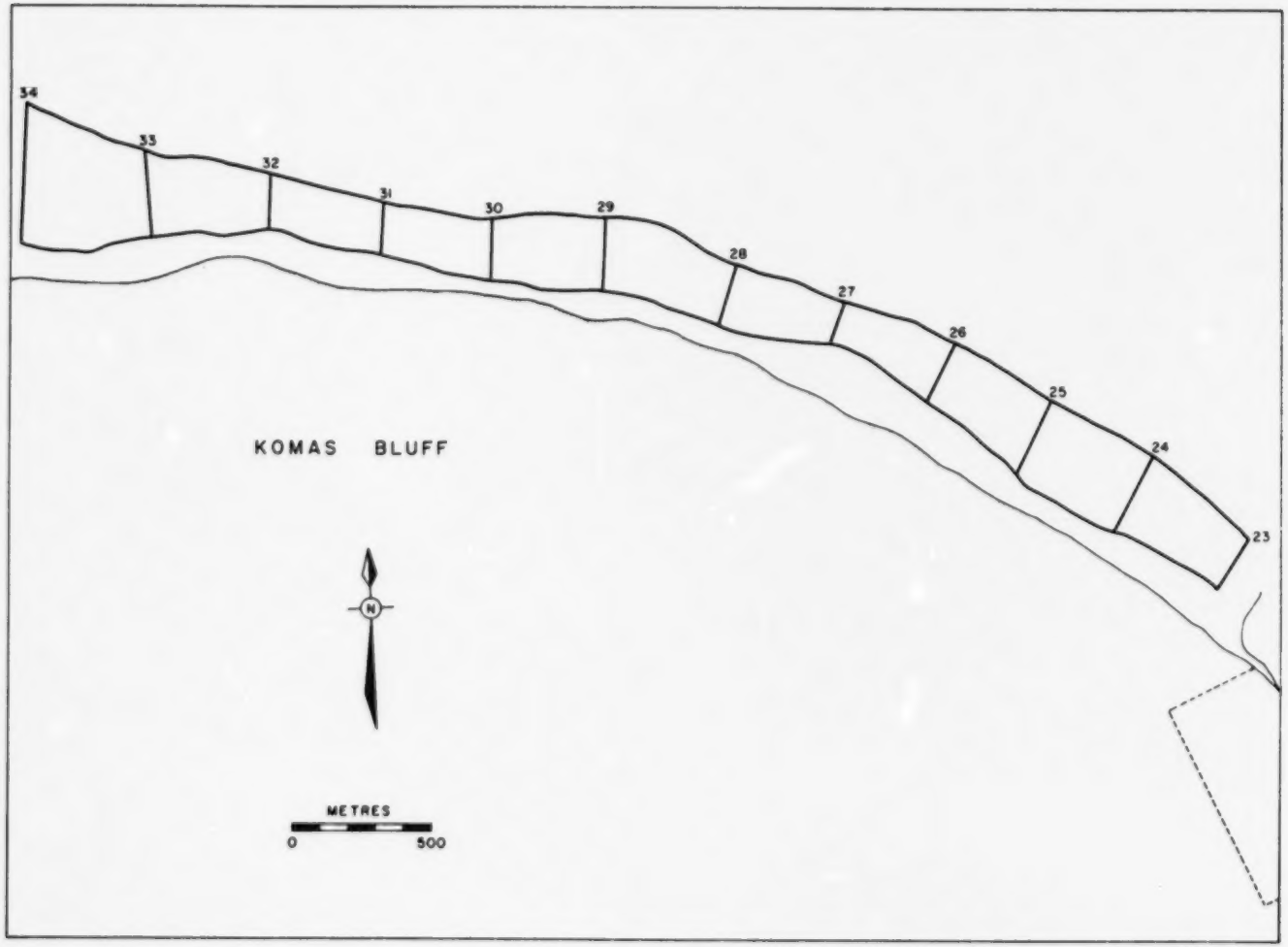

Fig. 7. Herring spawn at Komas Bluff on Denman Island, surveyed by divers in 1985, with transect locations shown.

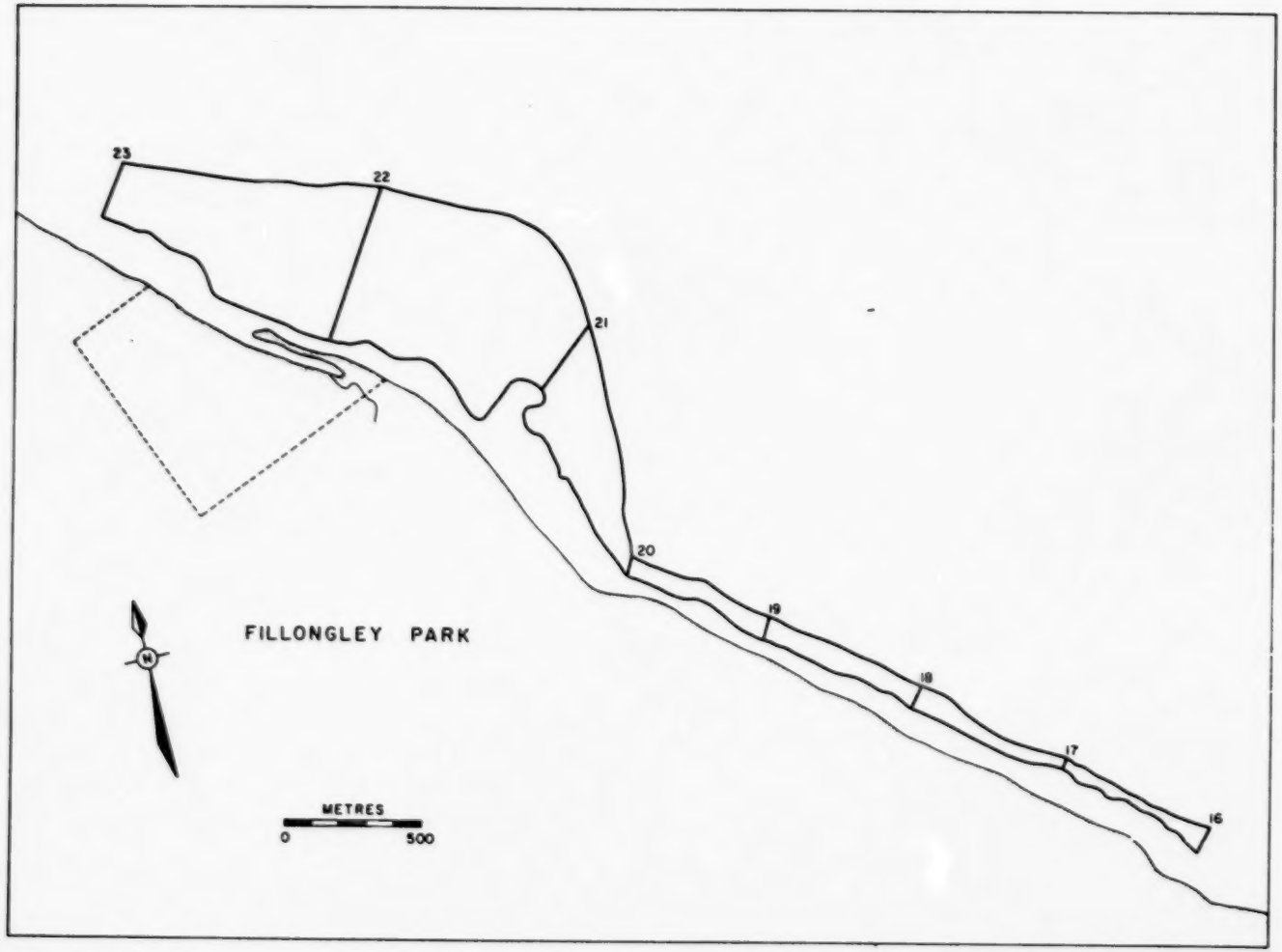

Fig. 8. Herring spawn at Fillongley Park on Denman Island, surveyed by divers in 1985, with transect locations shown.

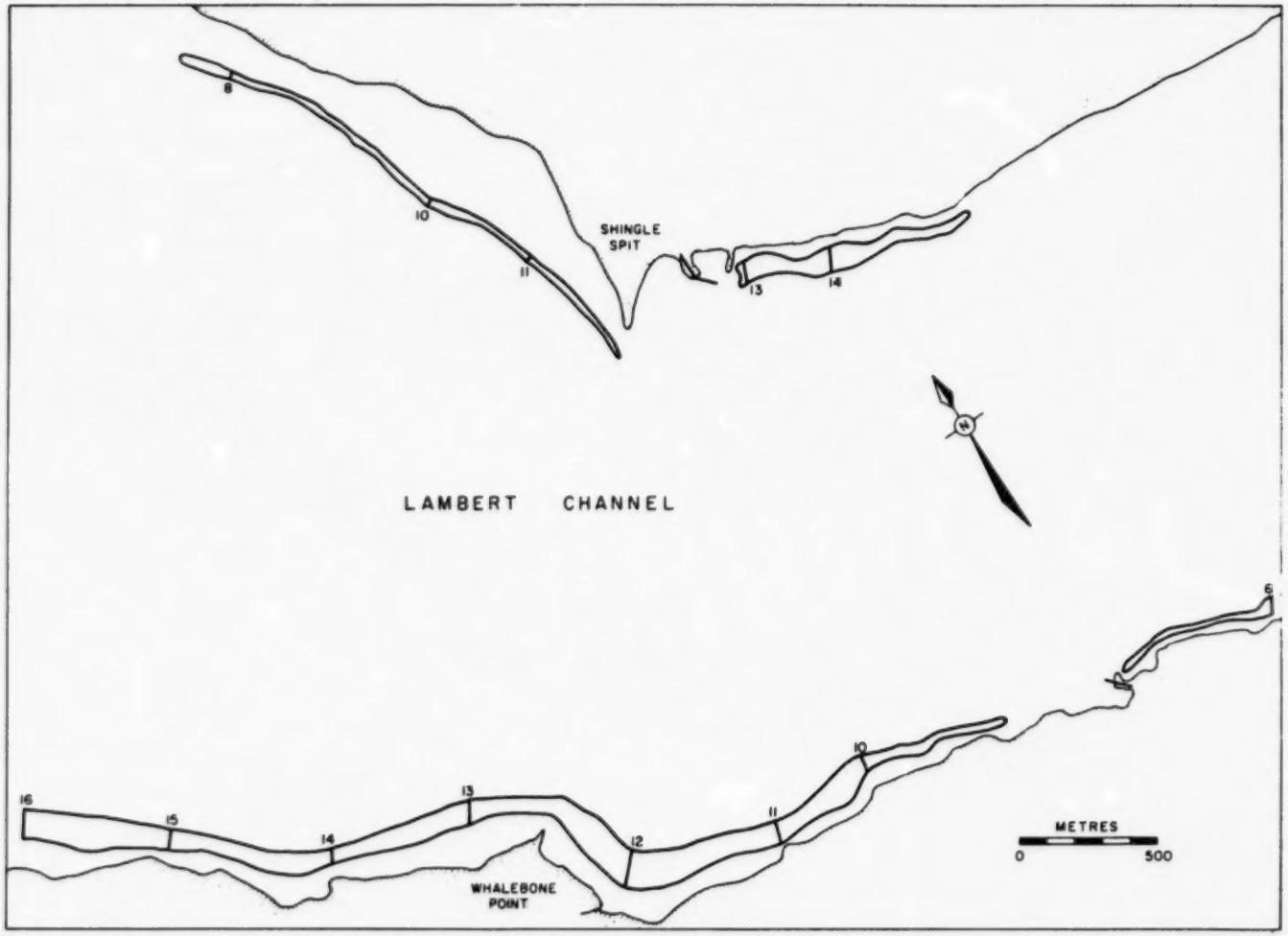

Fig. 9. Herring spawn in Lambert Channel including the spawn on both Denman and Hornby Islands, surveyed by divers in 1985, with transect locations shown.

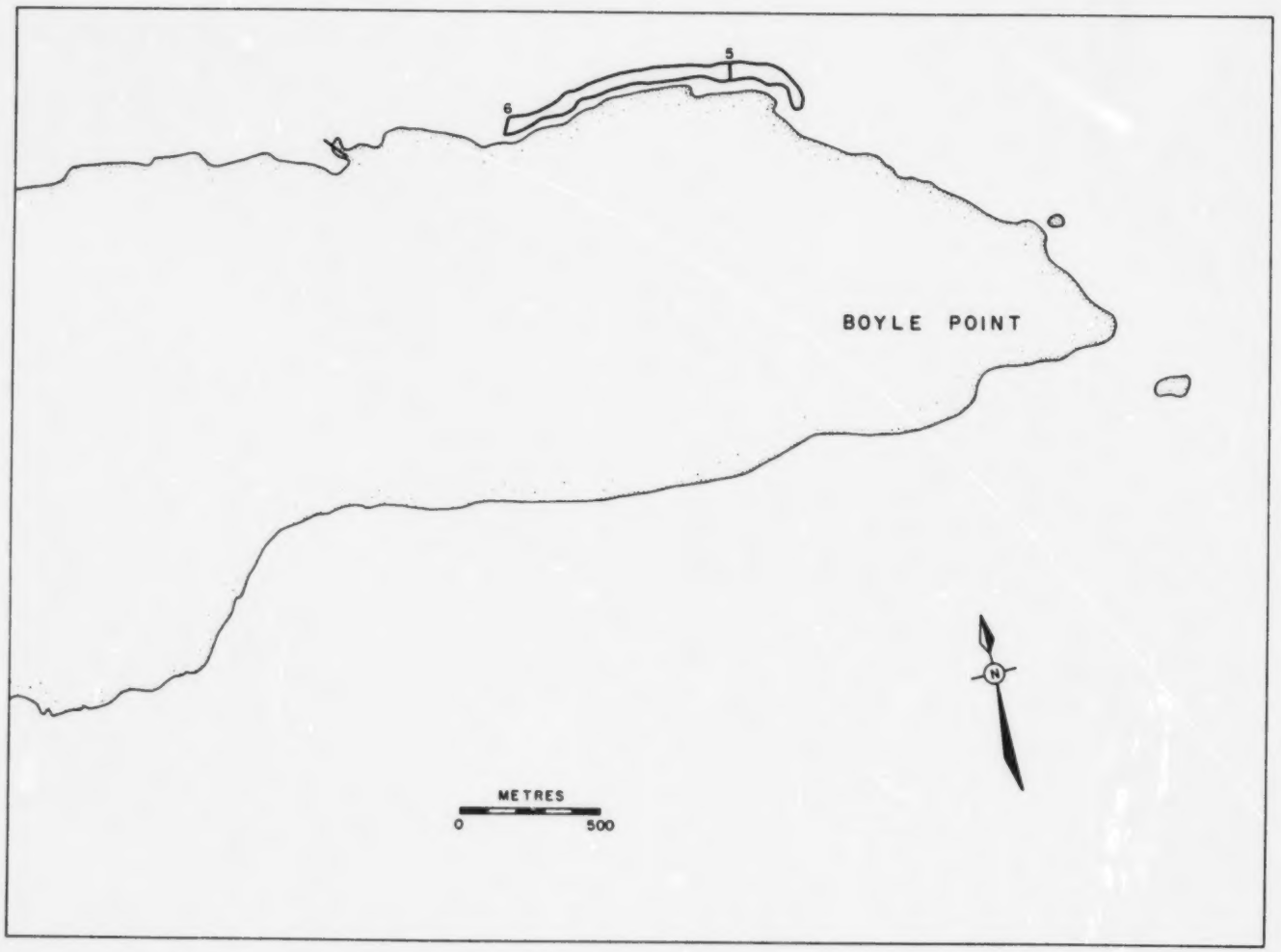

Fig. 10. Herring spawn at Boyle Point on Denman Island, surveyed by divers in 1985, with transect locations shown.

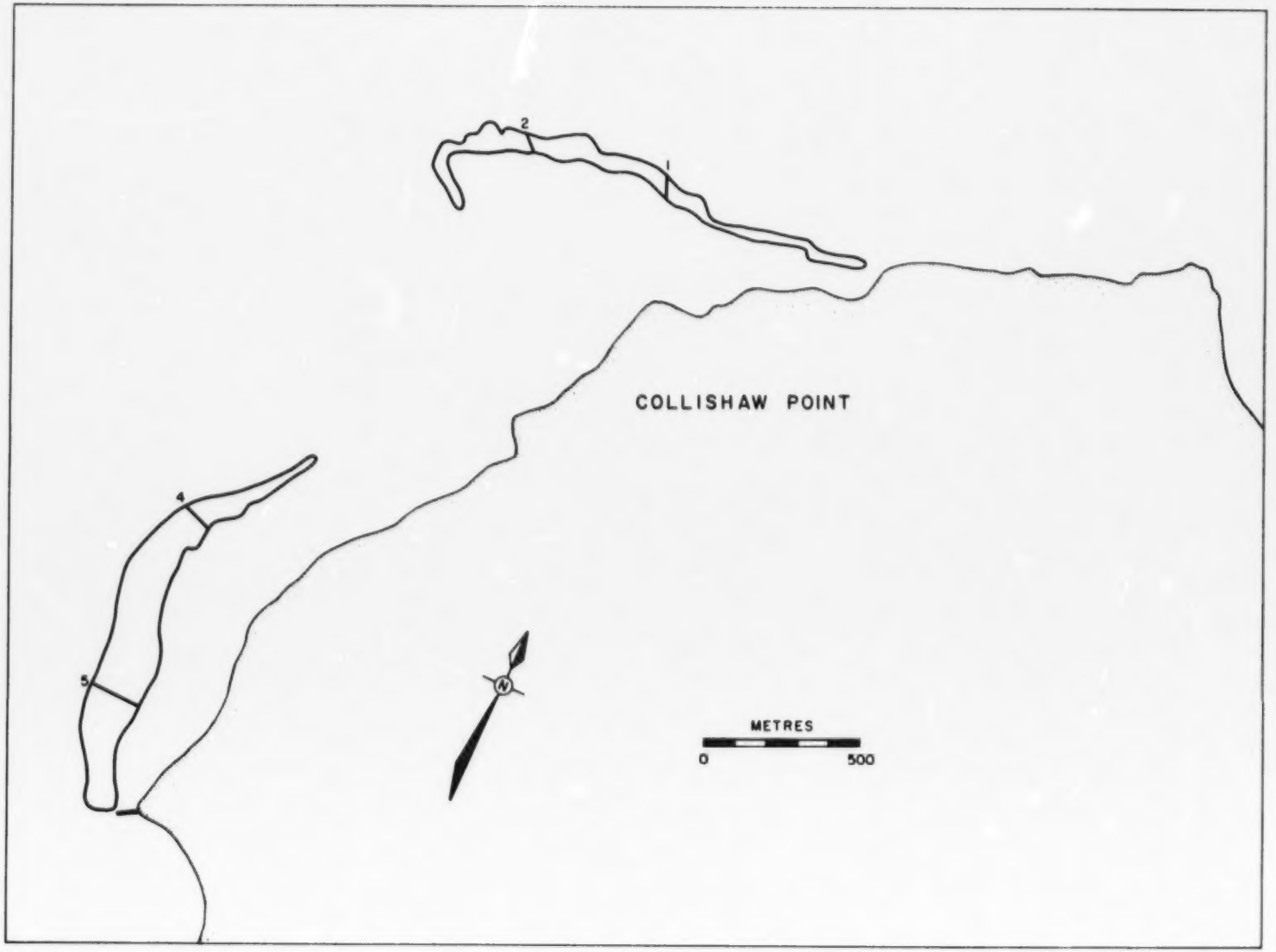

Fig. 11. Herring spawn at Collishaw Point on Hornby Island, surveyed by divers in 1985, with transect locations shown.

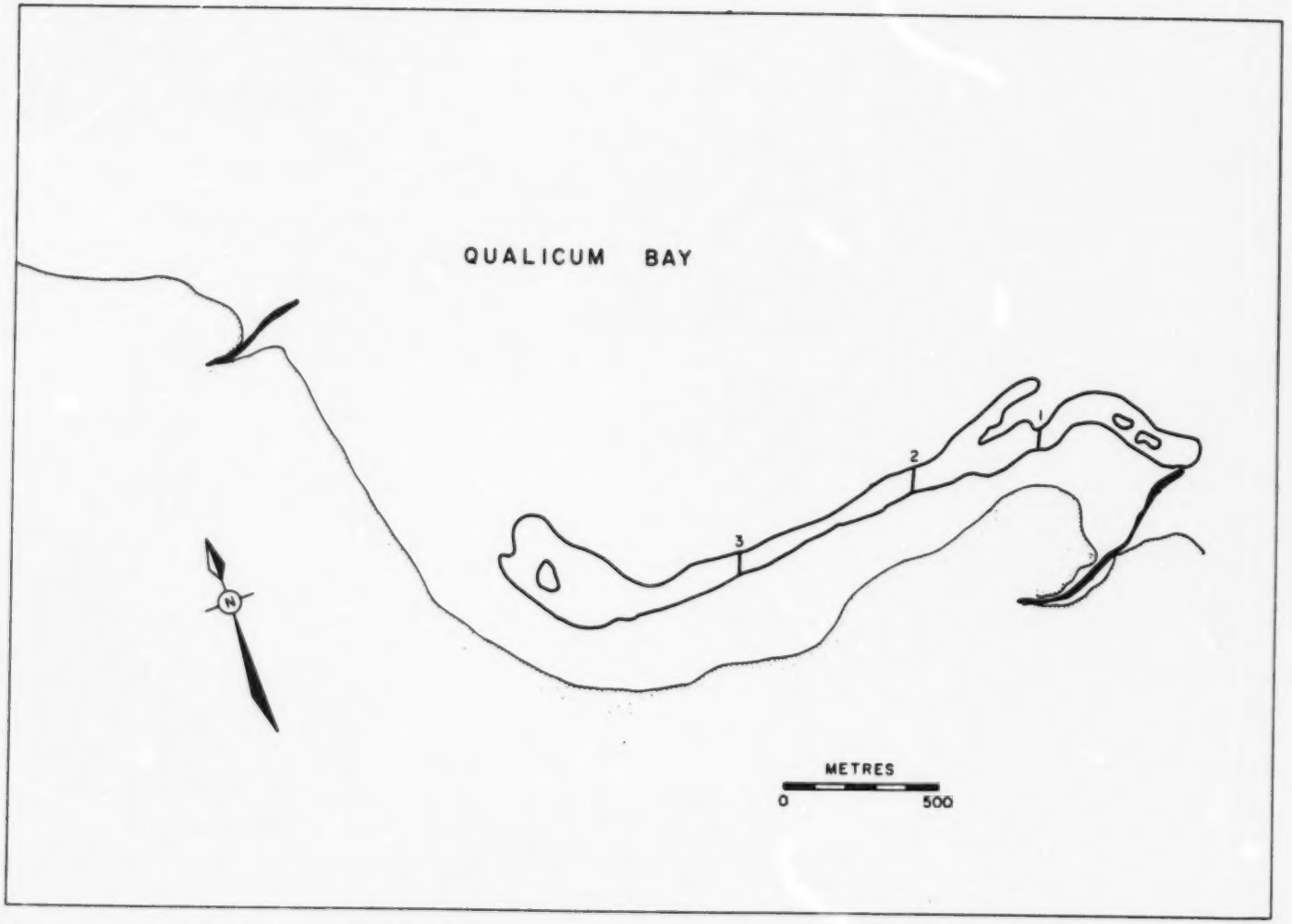

Fig. 12. Herring spawn at Nile Creek, surveyed by divers in 1985, with the transect locations shown.

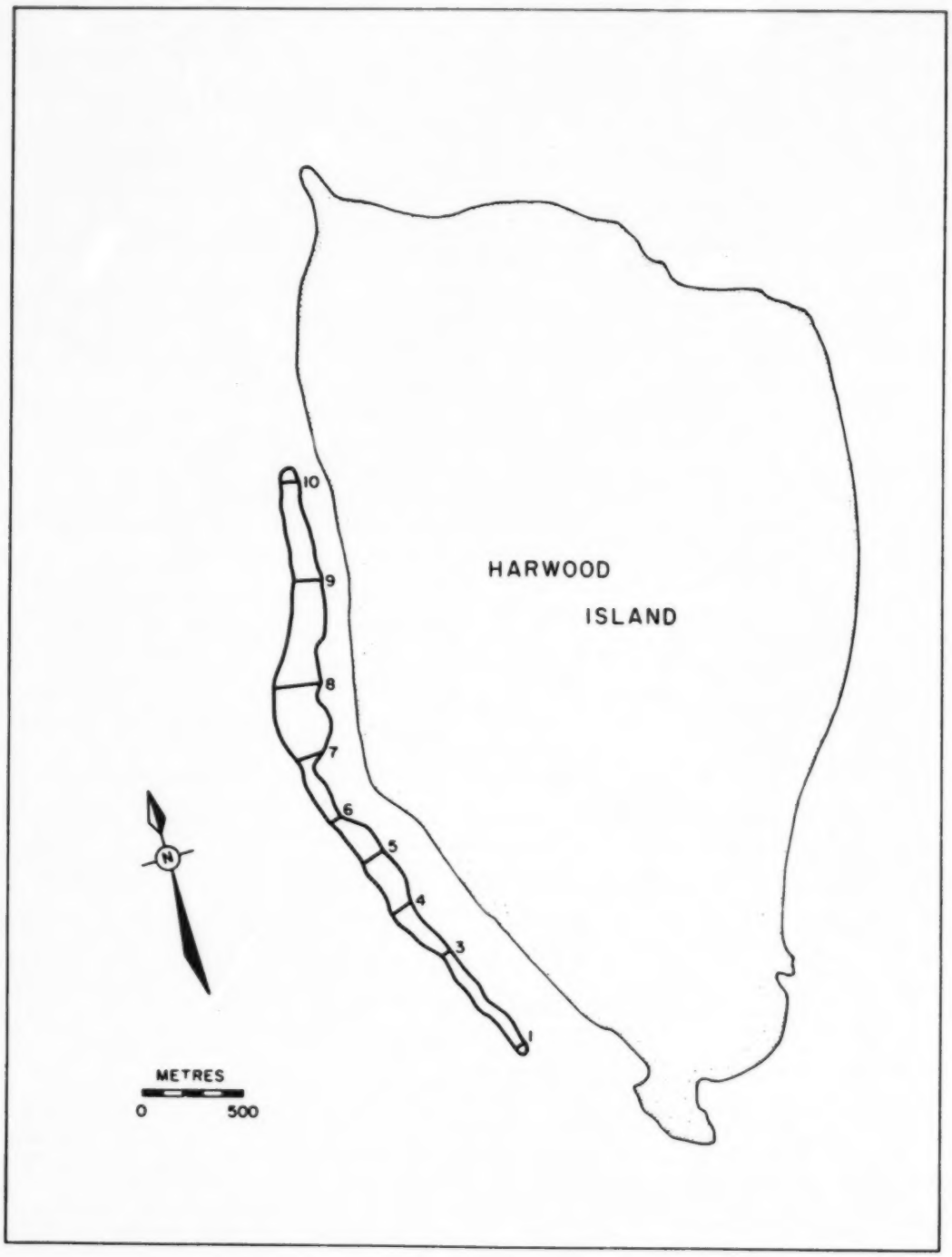

Fig. 13. Herring spawn at Harwood Island, surveyed by divers in 1985, with transect locations shown.

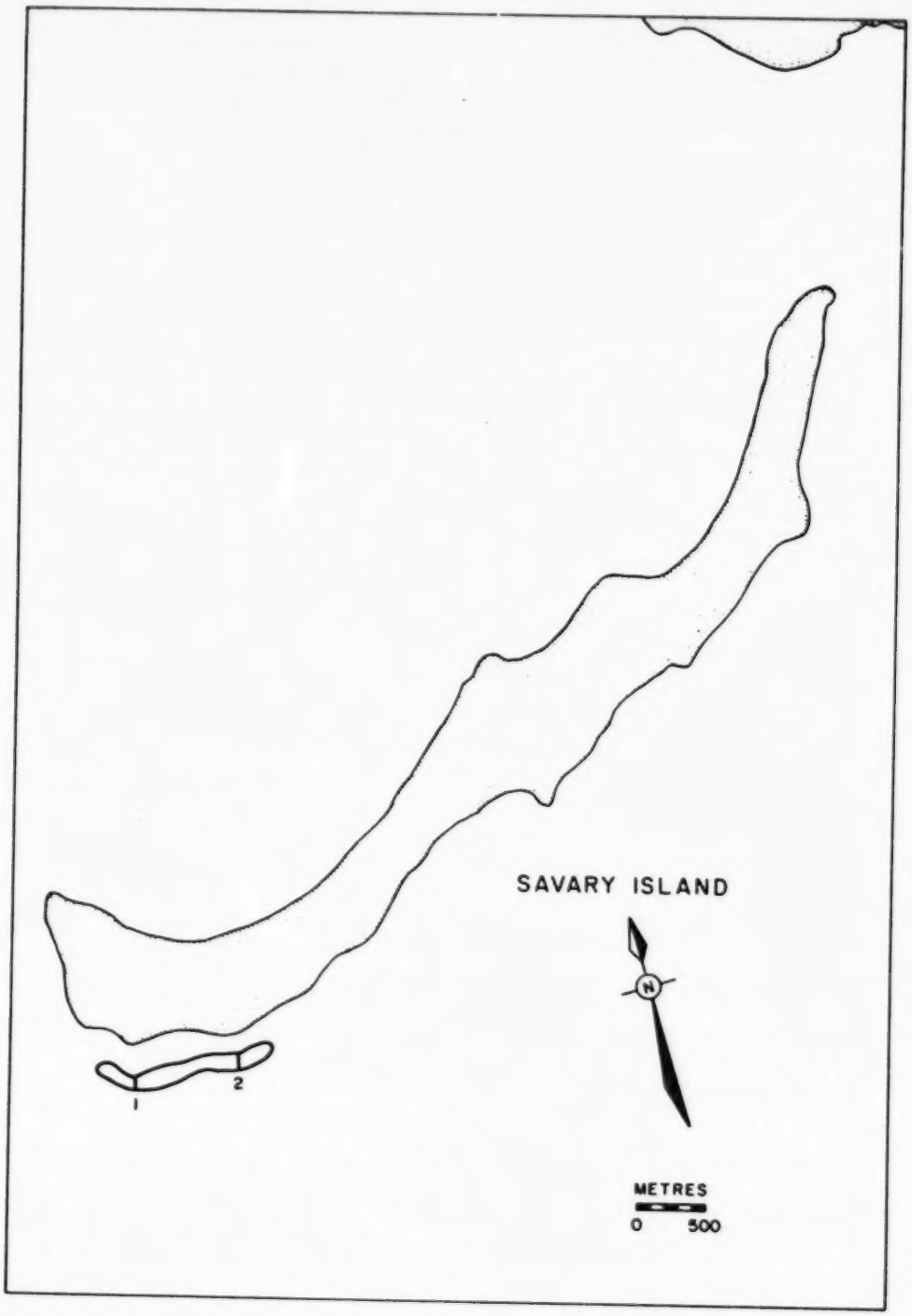

Fig. 14. Herring spawn on Savary Island, surveyed by divers in 1985, with transect locations shown.

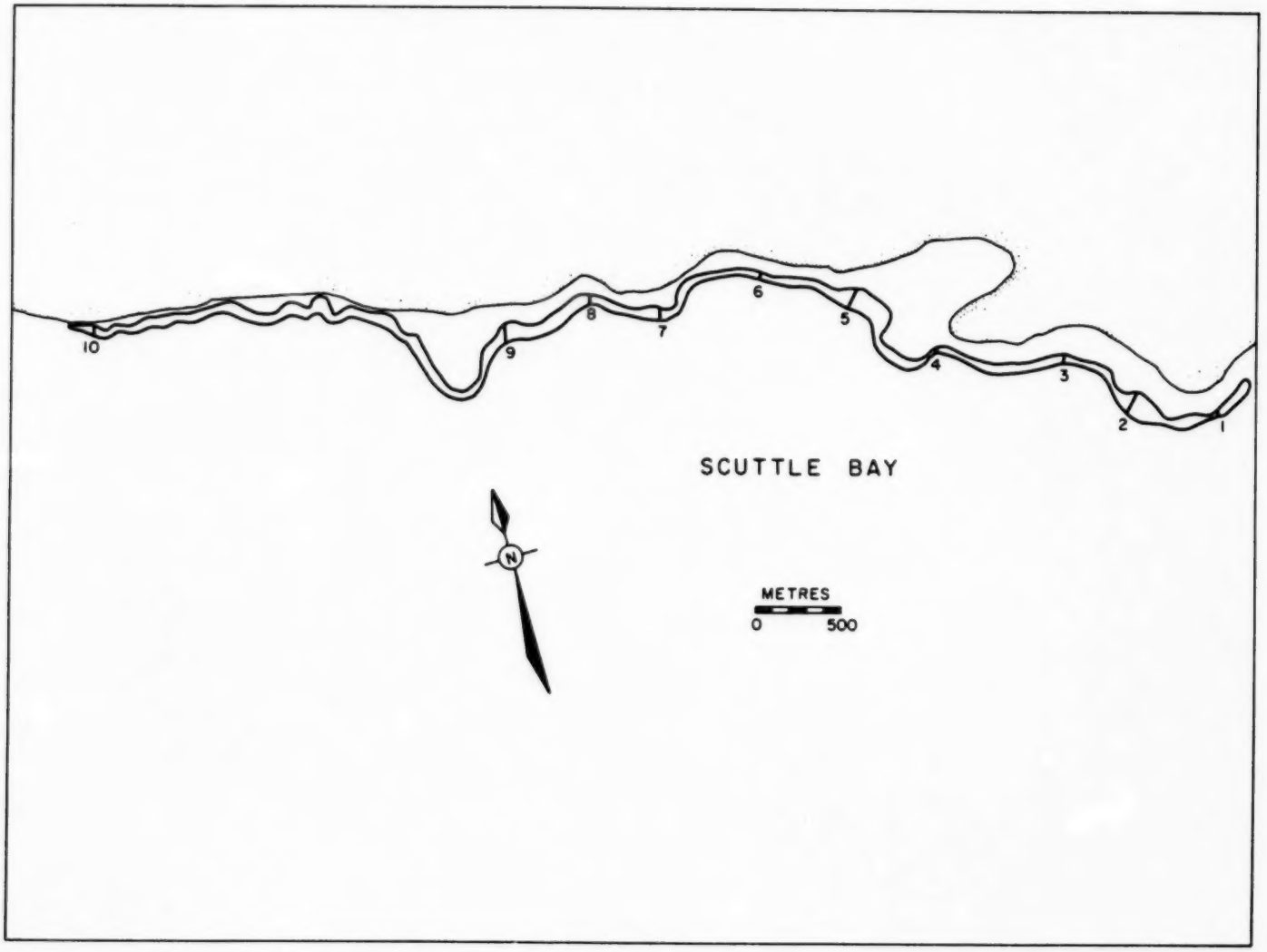

Fig. 15. Herring spawn at Powell River from Scuttle Bay north to Emmonds Beach, surveyed by divers in 1985, with transect locations shown.

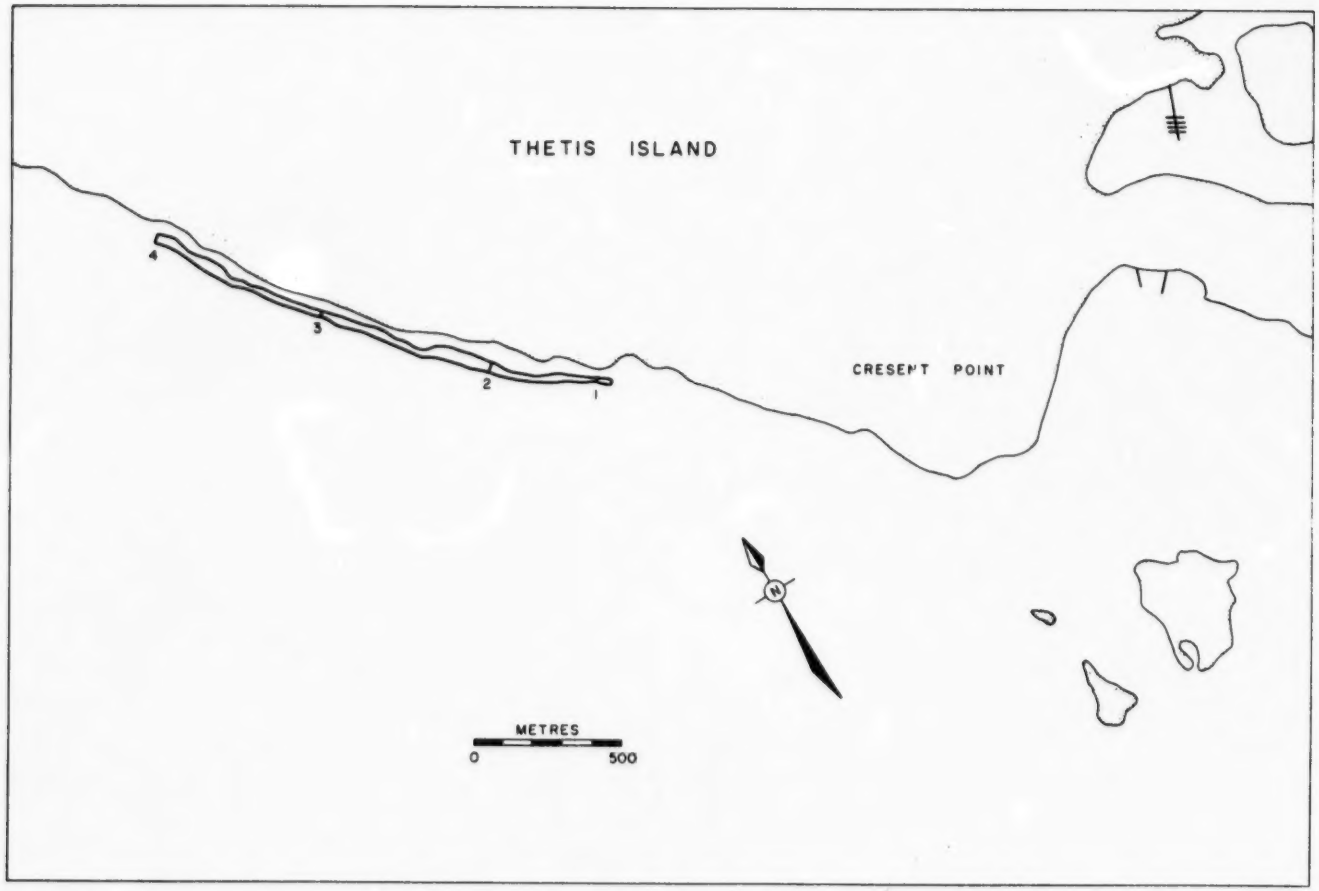

Fig. 16. Herring spawn on Thetis Island at Crescent Point, surveyed by divers in 1985, with transect locations shown.

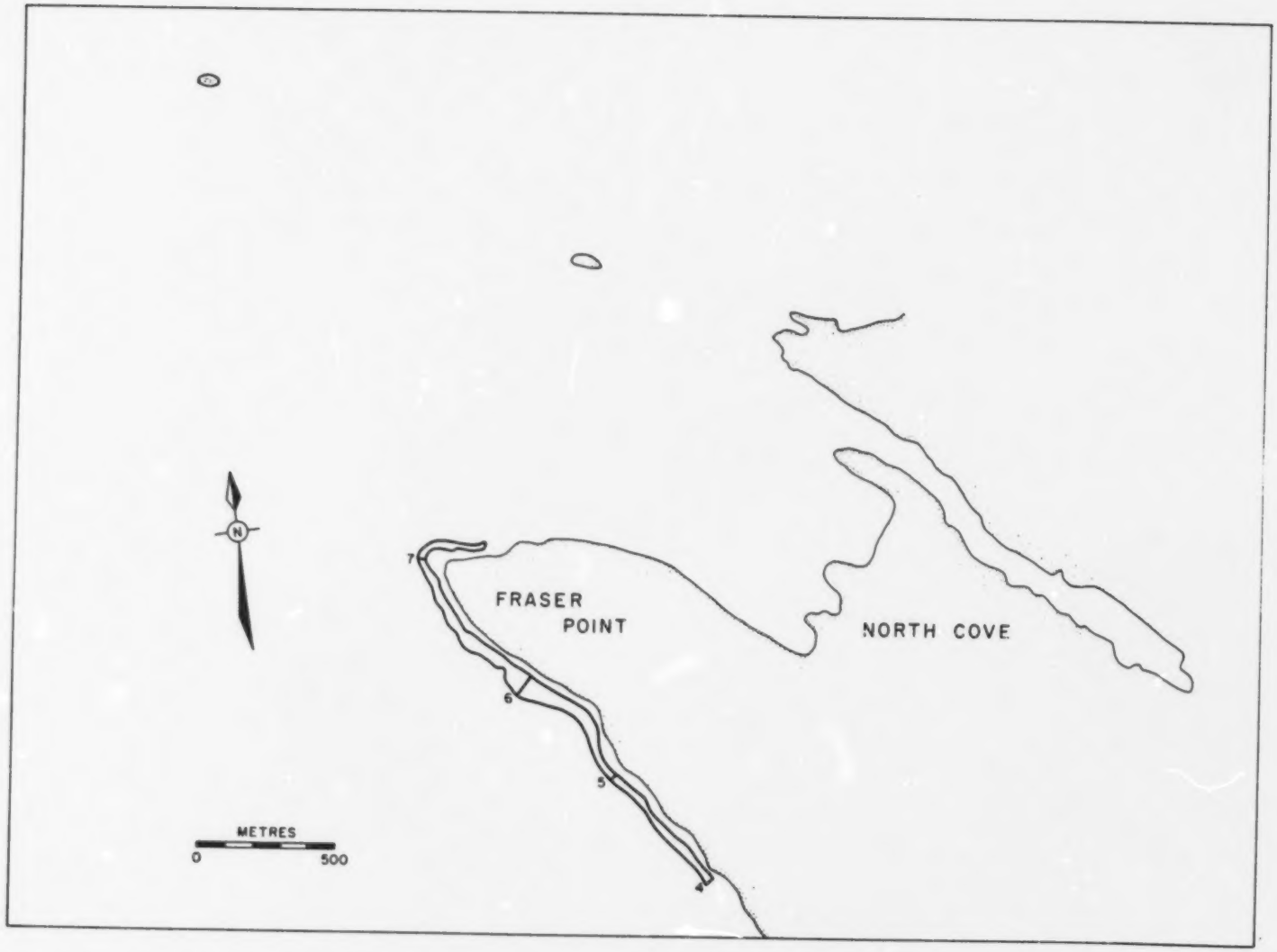

Fig. 17. Herring spawn on Thetis Island at Fraser Point, surveyed by divers in 1985, with transect locations shown.

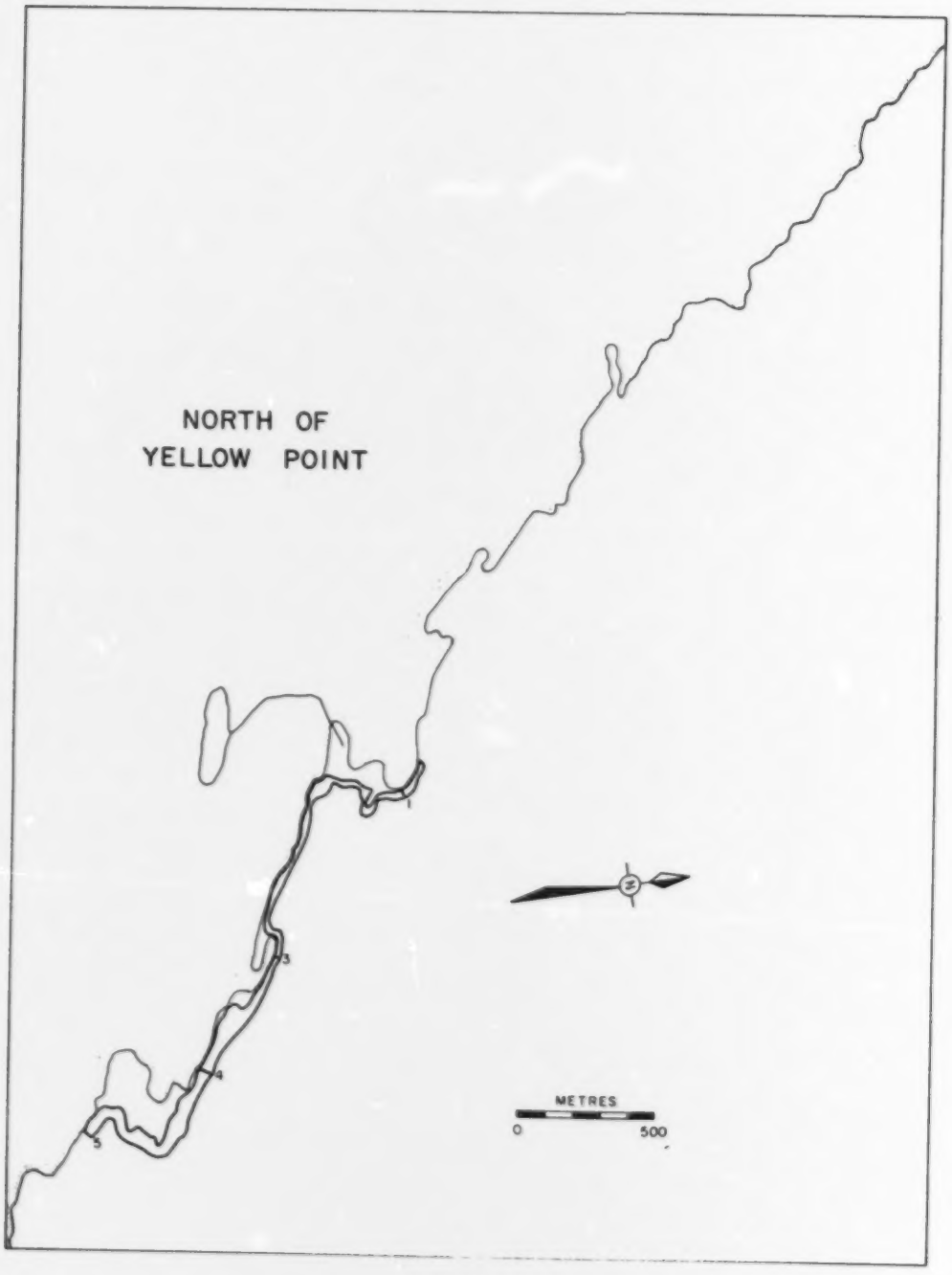

Fig. 18. Herring spawn north of Yellow Point in Stuart Channel, surveyed by divers in 1985, with transect locations shown.

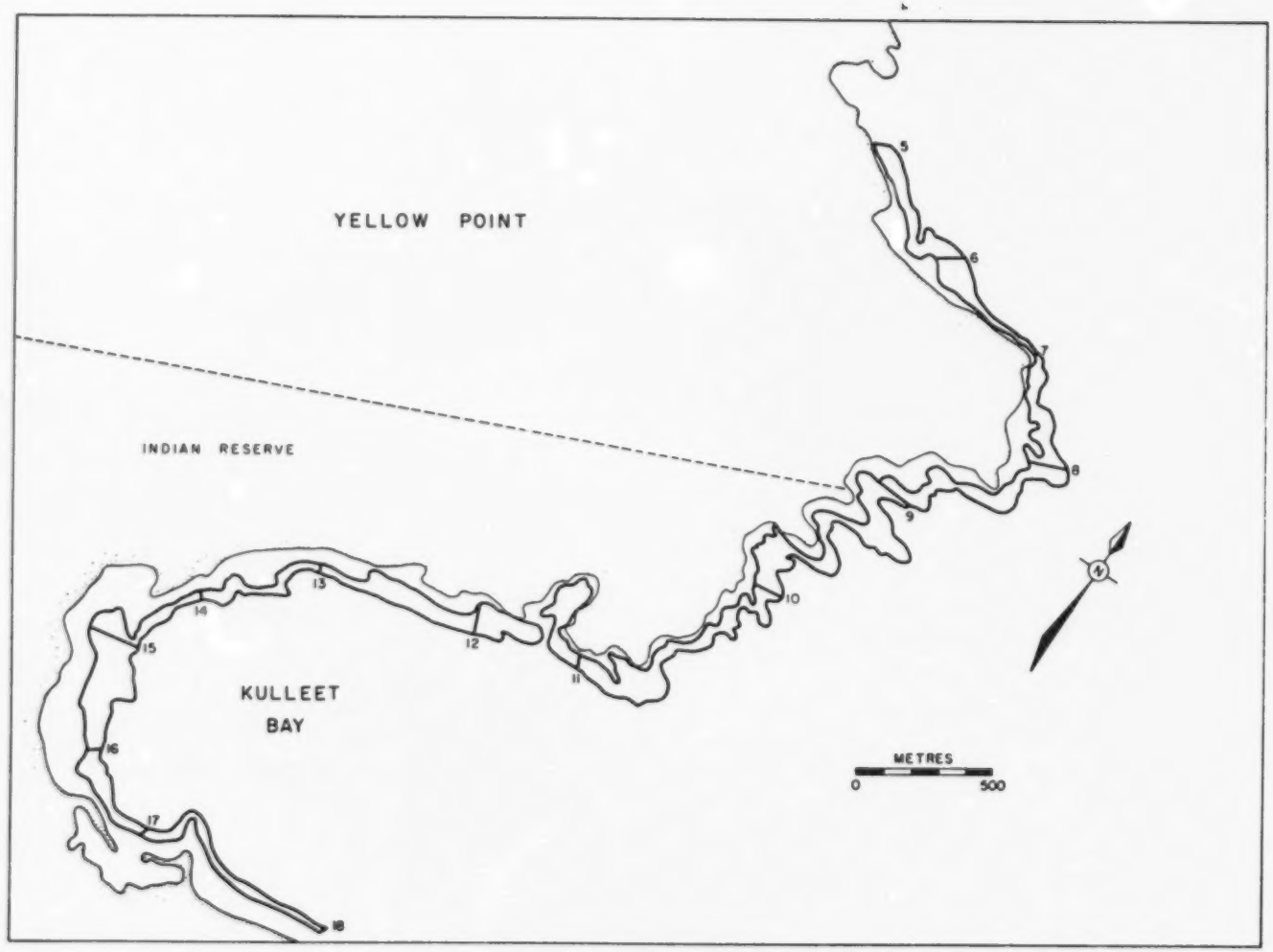

Fig. 19. Herring spawn from Yellow Point to Kulleet Bay, surveyed by divers in 1985, with transect locations shown.

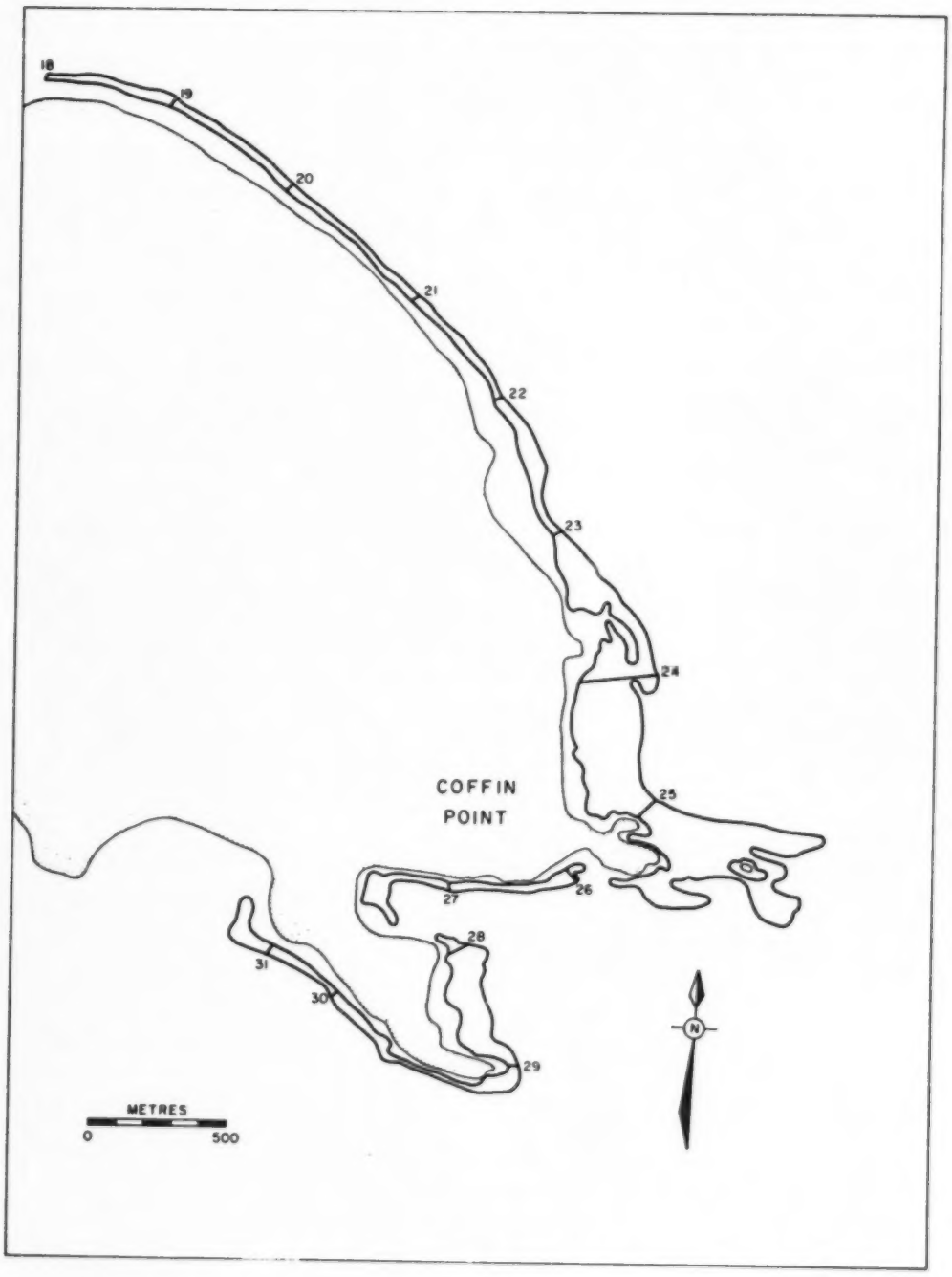

Fig. 20. Herring spawn from Kulleet Bay to Coffin Point, surveyed by divers in 1985, with transect locations shown.

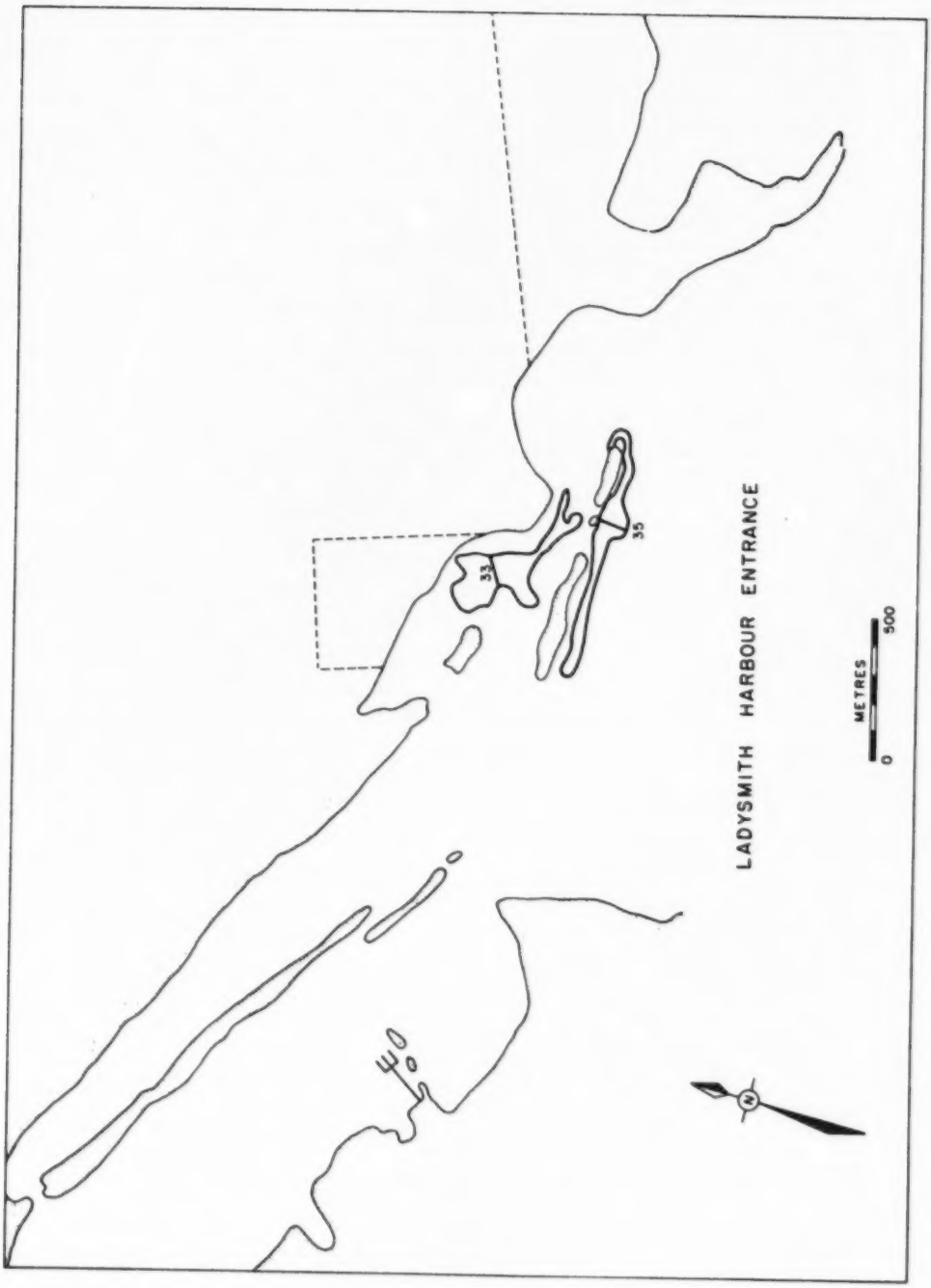

Fig. 21. Herring spawn from Sharpe Point to Dunsmuir Islands, surveyed by divers in 1985, with transect locations shown.

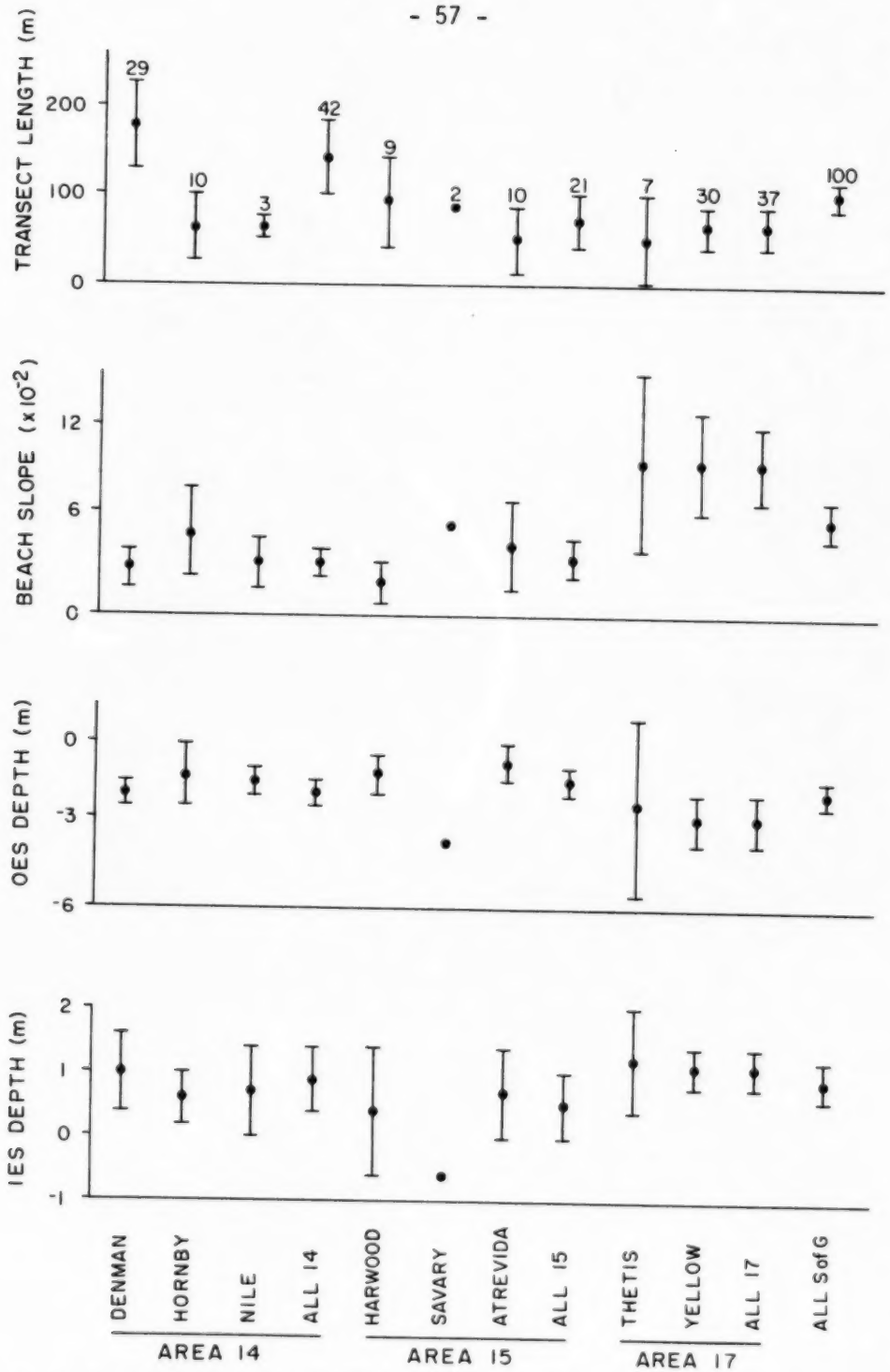

Fig. 22. Physical description of transects along which spawn survey information was collected by divers in 1985 in Georgia Strait. Average (with 95% C.I.) transect lengths, beach slopes, depth above (+) and below (-) chart datum of outer edge of spawn (OES DEPTH) and inner edge of spawn (IES DEPTH) and no. of transects sampled are shown.

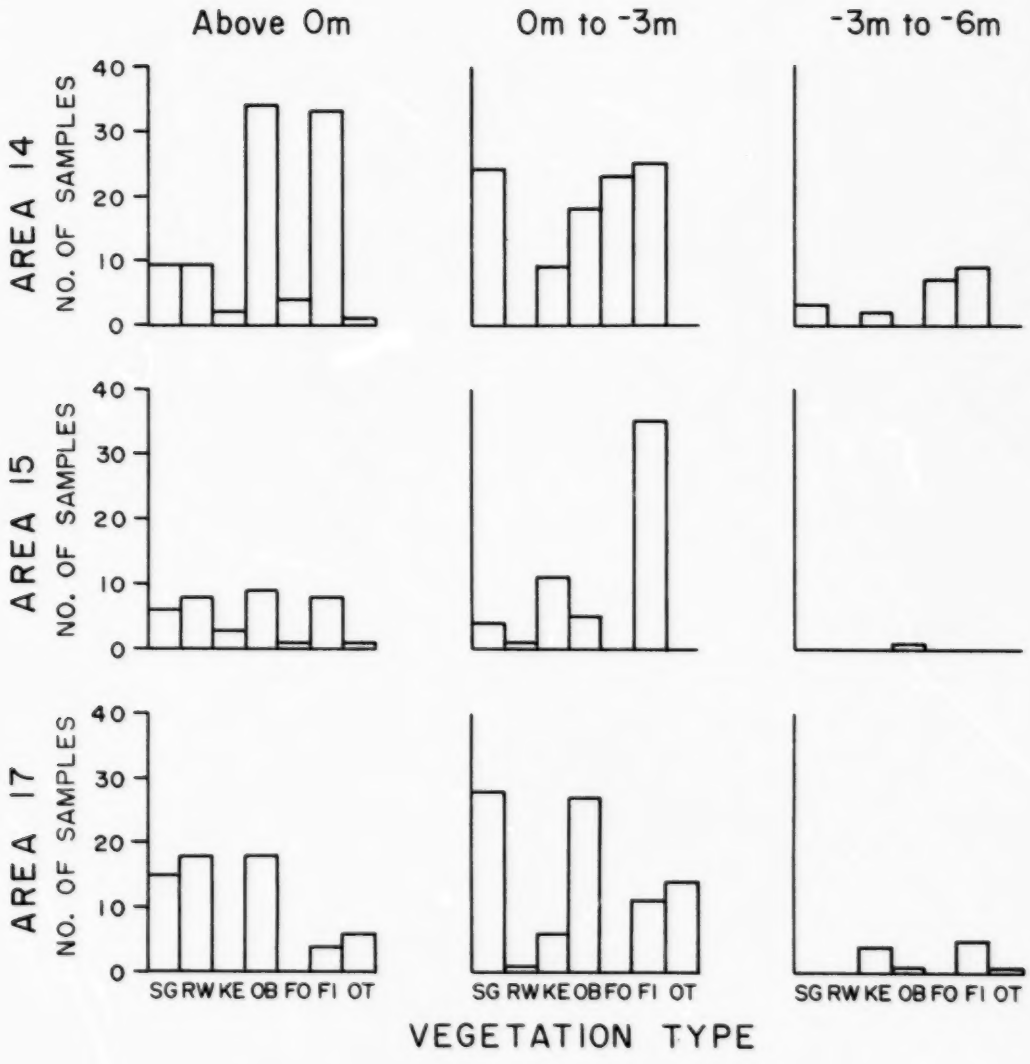

Fig. 23. Dominant vegetation types upon which eggs were deposited, summarized by Statistical Area and depth intervals [intertidal (above chart datum), upper subtidal (0 to 3 m below chart datum), and middle subtidal (3 to 6 m below chart datum)] for spawns surveyed by divers in Georgia Strait. (SG = sea grasses, RW = rockweed, KE = kelp, OB = other brown algae, FO = foliose red algae, FI = filamentous red algae.)

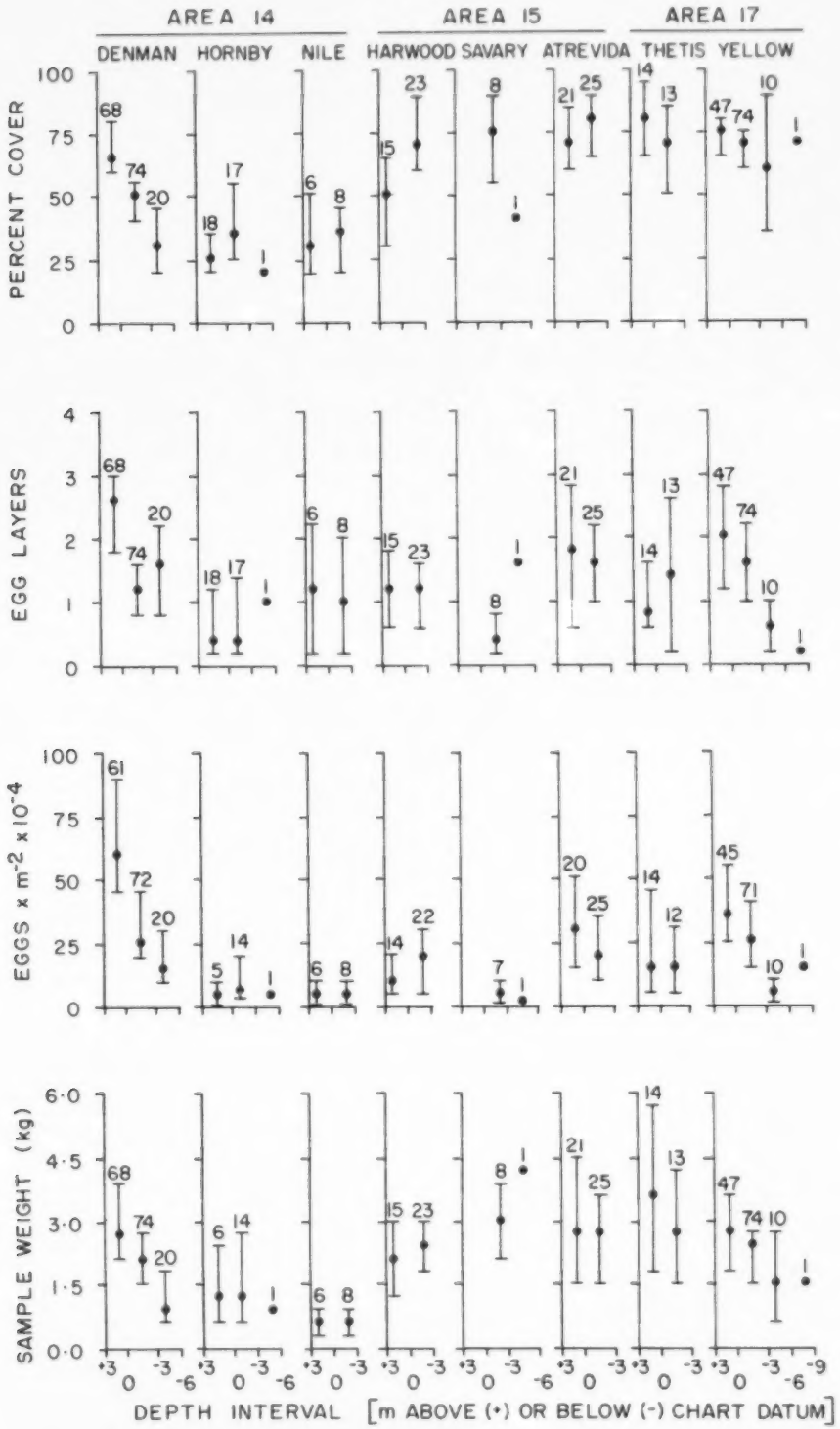

Fig. 24. Percent cover of vegetation, layers of eggs, eggs density, and sample biomass (Wilcoxian median and 95% C.I.) by depth interval [intertidal (above chart datum), upper subtidal (0 to 3 m below chart datum), middle subtidal (3 to 6 m below chart datum), and lower subtidal (deeper than 6 m below chart datum)] for spawns surveyed by divers in Georgia Strait in 1985. Sample numbers are shown above C.I. bar.

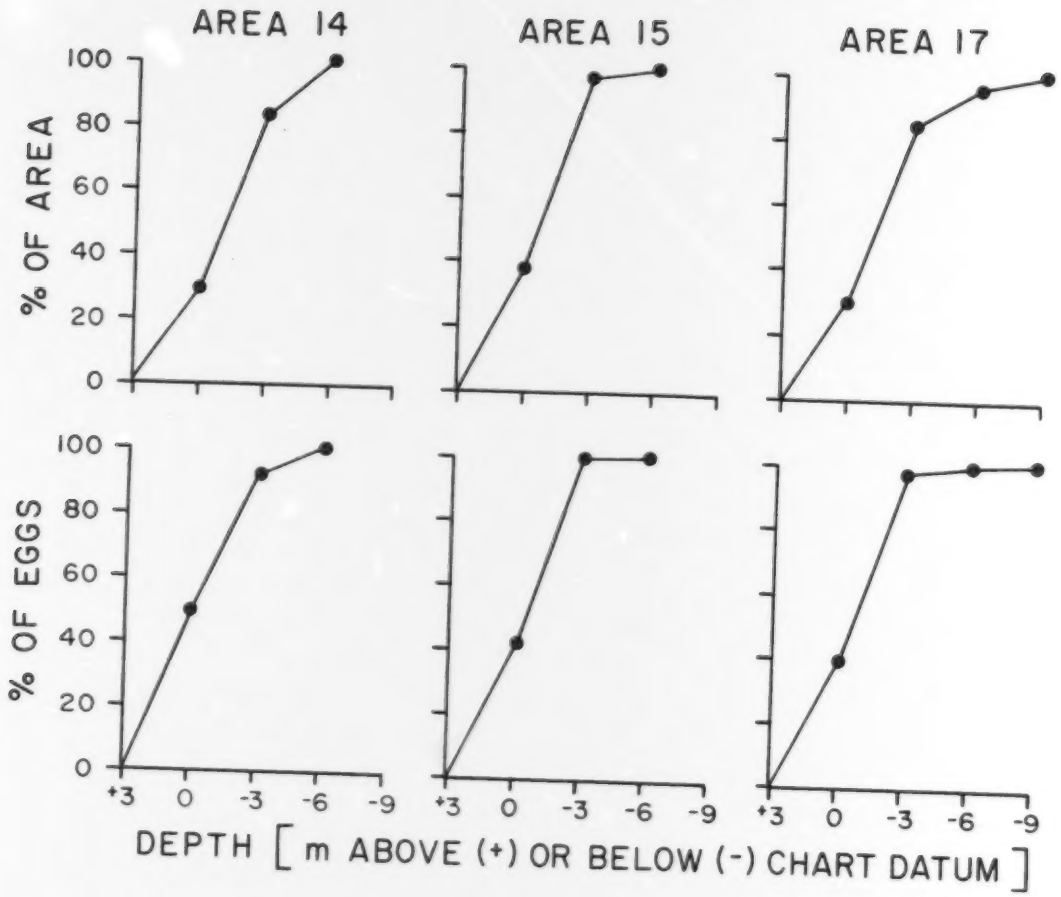

Fig. 25. Distribution of spawn area and eggs by depth interval [intertidal (above chart datum), upper subtidal (0 to 3 m below chart datum), middle subtidal (3 to 6 m below chart datum), and lower subtidal (deeper than 6 m below chart datum)] for spawns surveyed by divers in Georgia Strait in 1985.